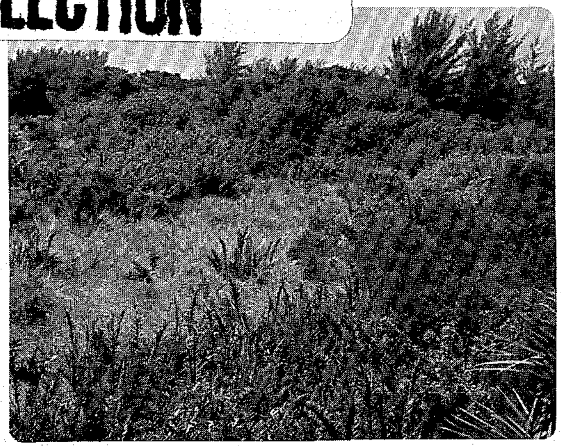
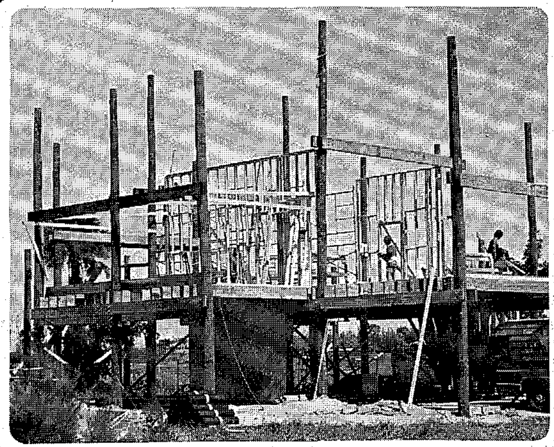
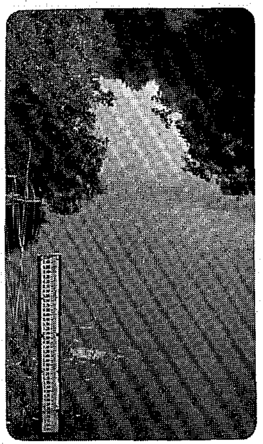
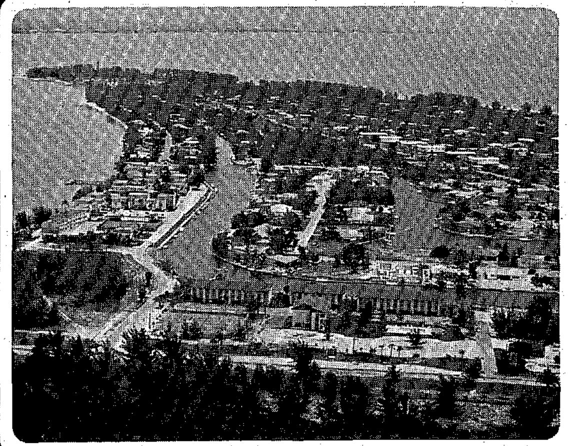
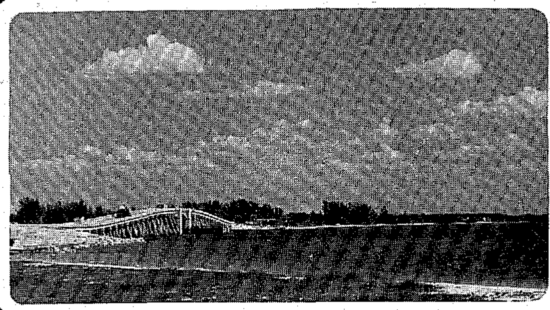
The Sanibel Report

Formulation of a Comprehensive Plan Based on Natural Systems

by John Clark

The Conservation Foundation

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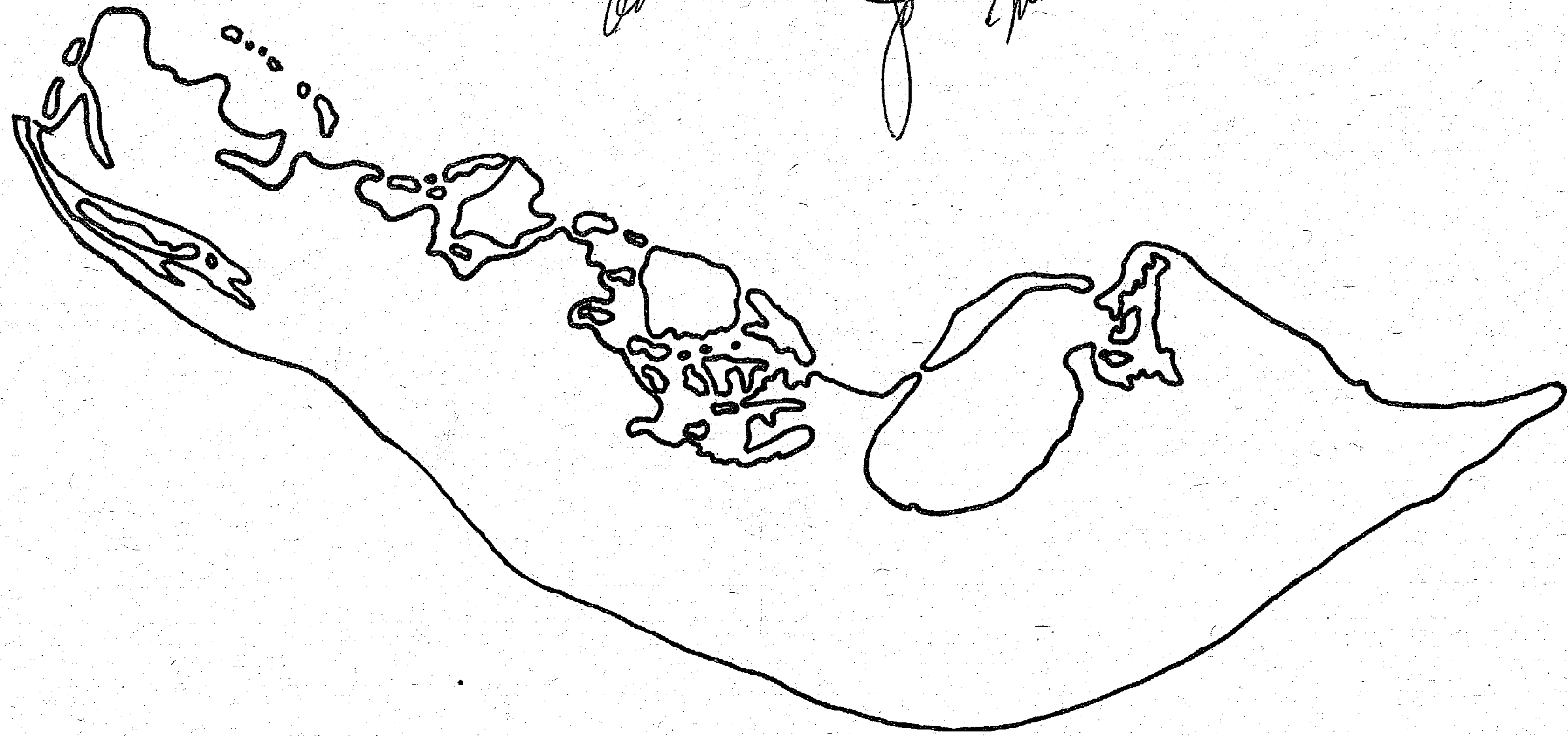
Bob Knecht
with deepest
admiration and
best wishes
J. Clark
March 30 1972



The Conservation Foundation is a non-profit research and communication organization dedicated to encouraging human conduct to sustain and enrich life on earth. Since its founding in 1948, it has attempted to provide intellectual leadership in the cause of wise management of the earth's resources. It is now focusing increasing attention on one of the critical issues of the day—how to use wisely that most basic resource, the land itself.

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The Conservation Foundation
Washington, D.C.

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INTRODUCTION

On November 5, 1974, the citizens of Sanibel Island, Florida, took their destiny into their own hands. More than a thousand of them went to the polls; a sizable majority—64 percent—voted to incorporate the island as a city, empowered to cope firmly with the pressures of development. A building boom, spurred by the construction in 1963 of a causeway joining Sanibel to the southwestern Florida mainland, had soared nearly out of control, depleting the resources of the 12-mile-long barrier island.

Lying broadside to the path of seastorms and hurricanes, Sanibel stands as the major defense against battering storm waves and hurricanes in central Lee County—a stance that also makes the island beach a treasure trove of seashells. Each year nearly a million people visit Sanibel to collect shells, walk the beach, or enjoy the other natural values of the island. A major site for birding, fishing, and nature study, Sanibel also lures more than 800,000 visitors annually to its J.N. "Ding" Darling National Wildlife Refuge.

Until 1974, Sanibel was governed by the Lee County Board of Commissioners. Despite Sanibel's unique character, the board classified the island as though it were any mainland area ripe for intensive development. By permitting construction of condominiums on frontal dunes and conversion of wetlands into golf estates, the county zoning of Sanibel would have allowed a population of more than 90,000 (currently, the peak season population is about 12,000). Not only was nature's zoning violated by such inappropriate uses, but life and property were endangered by the obvious threat of tropical hurricanes.

On December 16, 1974, a few weeks after the vote for incorporation, the new Sanibel city government took over. It immediately issued a moratorium on new building permits and began to devise a strategy for conserving its threatened land and water resources, its beaches and mangroves, its drinking water and wildlife—in a word, its remarkable quality of life.

The Sanibel Planning Commission began work on the new comprehensive plan within a few days after the installation of the new city government. To provide professional assistance, the city engaged the Philadelphia planning firm of Wallace, McHarg, Roberts and Todd, and the Chicago law firm of Ross, Hardies, O'Keefe, Babcock and Parsons. The planning process is described in some detail in Part III of this report.

The process reached its culmination on July 19, 1976, when the plan received final approval, ordinances were passed, and the general moratorium on development was lifted. The Sanibel Plan provides for long-term conservation of natural resources as well as a reasonable amount of growth. The planning methods adopted: 1) set a future limit on population consistent with natural limits, notably those imposed by water resources and by the imperative of evacuation before hurricanes; 2) distribute the permitted number of new structures (about 2,000) over the developable land in accordance with the carrying capacity of the natural systems; 3) establish a strong set of performance standards for all development; 4) develop a scientific plan for restoration of past ecologic damage (particularly to the water systems); and 5) provide for the highest level of continuing public participation.

The Conservation Foundation contributed to the planning process, not on behalf of the city government, but at the invitation of private citizen organizations concerned about natural systems. These organizations, particularly the Sanibel-Captiva Conservation Foundation, wanted to assist the planning effort by preparing a detailed natural systems analysis as well as recommendations for the conservation of natural resources and natural systems. The Conservation Foundation was asked to help, and funds for the work were raised by the Sanibel-Captiva Conservation Foundation from philanthropic organizations.

The Conservation Foundation began its study of Sanibel's natural systems in May 1975, through a team led by our senior ecologist, John Clark. Our work focused particularly on the carrying capacity of the natural systems. After a series of meetings to discuss our findings and recommendations with members of the Sanibel-Captiva Conservation Foundation, I presented them to the City Council on September 16, 1975. Many of those recommendations —though not all of them—were accepted by city officials and are reflected in the adopted plan.

The Conservation Foundation undertook its Sanibel work not only to help the citizens of Sanibel protect their natural systems, but also in an effort to improve the methodology of conservation. Specifically, we hoped to demonstrate the contribution that a thorough study of natural systems can make to the local planning process. Sanibel is particularly appropriate for such a demonstration because natural constraints on its development are unusually strong. The most dramatic of these constraints results from Sanibel's location in a storm hazard area; a severe hurricane could result in catastrophic property damage and perhaps serious loss of life. The island's highly permeable soils, unsuitable for septic tanks, also limit the type and intensity of development. In addition, much of Sanibel's surface is occupied by mangroves and interior wetlands, which serve as important habitats for animals and vegetation and perform other vital functions as well. Many of these wetlands are included in natural preserves, some governmental and some private, which together occupy more than 45 percent of the island's surface.

The Sanibel Report serves several purposes. It formally conveys The Conservation Foundation's conclusions and recommendations to the Sanibel-Captiva Conservation Foundation and to the citizens of Sanibel. It describes the Sanibel natural systems study in detail. It presents verbatim those elements of the Sanibel Plan that deal with major natural systems. In sum, it presents a basic case study of how the carrying capacity of a natural system can be determined and then used in formulating a comprehensive land-use plan. The lessons learned on Sanibel Island, based on solid, scientific study, apply not to Sanibel alone, but to countless small communities whose ecology imposes natural limits to growth.

The Conservation Foundation extends special thanks to those who made our Sanibel study and this publication possible: the Sanibel-Captiva Conservation Foundation, and particularly Mr. Erard A. Matthiessen; the American Conservation Association, the Mary Cary Flagler Charitable Trust, the Andrew W. Mellon Foundation, the Anne S. Richardson Fund, and the Taylor Foundation.

William K. Reilly
President
The Conservation Foundation

November 1976

Acknowledgments

Our research on the natural systems of Sanibel and the publication of this report were made possible by the efforts of members of the Sanibel-Captiva Conservation Foundation. They raised the funds for the study and also provided extensive on-site assistance. One member of the foundation, Erard A. Matthiessen, is primarily responsible for the genesis of our study. Members who made particularly important contributions during the progress of the work include: Richard Workman, Executive Director; Dewitt Jones, President; and Charles J. Wilson and Ann Winterbotham, past presidents. We are also grateful for the help of Donald Whitehead and Malcolm Beattie.

The continuing support of Porter Goss, Mayor of Sanibel, and C. Duane White, Chairman of the Planning Commission, helped immeasurably. The following Sanibelians participated in our workshops: Griffing Bancroft, Malcolm Beattie, Edward Konrad, Bill Hammond, Mada Harrison, Phoebie Haynie, Robert Haynie, Dewitt Jones, Eddie Levy, Patsy Simmons, Donald Whitehead, Charles Wilson, and Ann Winterbotham.

Members of The Conservation Foundation staff who contributed to the study were John S. Banta, J. Clarence Davies, Robert Healy, Jack Noble, and Jeffrey A. Zinn. Claudia Wilson assisted with art and editorial matters. Laura O'Sullivan handled all administrative details of the work and produced the manuscript. David Sleeper and Jerry Kline edited the manuscript; and Celine Seymour provided valuable editorial assistance.

Our team of technical experts deserves the highest praise for their skill and dedicated efforts. The six basic systems reports (included in the Appendix) were prepared by Taylor R. Alexander, Mark Brown, William K. Byle, Jr., Eric J. Heald, Thomas M. Missimer, John B. Morrill, Stanley R. Riggs, Martin A. Roessler, Durbin C. Tabb, and Richard Workman. Other consultants who contributed to the data base reports, or assisted in other ways, include: Gary Beardsley, George R. Campbell, James H. Hartwell, Oliver H. Hewitt, Jane McCarthy, Peter Rosendahl, Albert R. Veri, Langdon S. Warner, and G. Kenneth Young.

Exceptionally valuable technical contributions were made by Maurice W. Provost of the Florida Medical Entomology Laboratory, William Hammond of the Environmental Education Center, and D. H. Boggess of the U.S. Geological Survey. Other advisors and cooperators whose help is gratefully acknowledged include: Kelly Brooks (University of Florida), Louis C. Burney and Larry Pearson (Coastal Coordinating Council, State of Florida), Nathaniel P. Reed, Ken Black, and Rudy Rudolph (U.S. Department of the Interior).

We are most grateful to the following foundations for grants in support of our natural systems study and the publication of this report: the American Conservation Association, the Mary Cary Flagler Charitable Trust, the Andrew W. Mellon Foundation, the Anne S. Richardson Fund, and the Taylor Foundation.

J.C.

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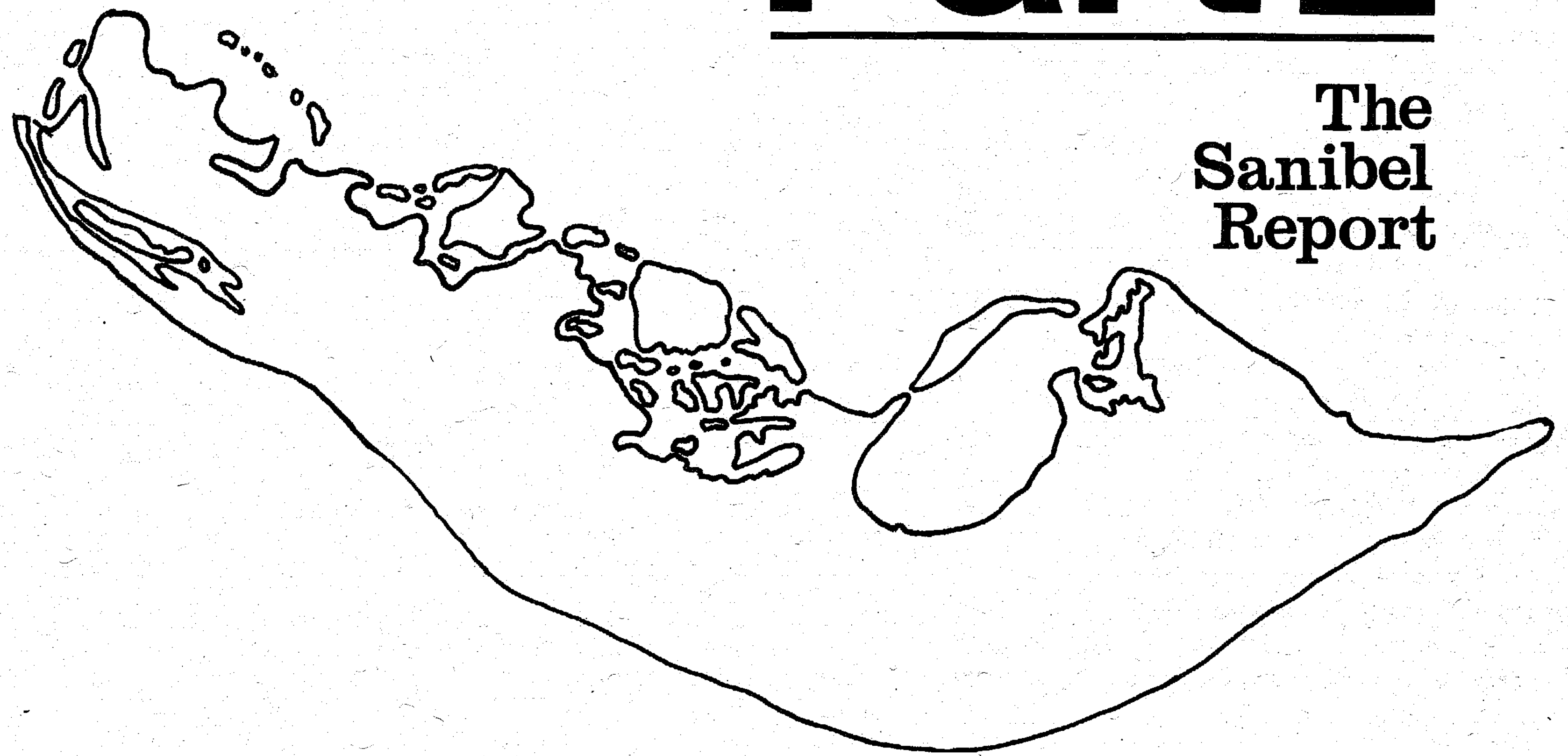
The Sanibel Report



CHAPTER 1

HISTORY OF THE ISLAND

The City of Sanibel occupies an 11,000-acre barrier island on the gulf coast of Florida, near the mouth of the Caloosahatchee River in Lee County. (Figure 1) The island has been shaped and formed by the wind and the sea into a corduroy of sand ridges that provide its structure, elevation, and character. Its geological age is only 5,000 years.

Early History

In 1513, Juan Ponce de Leon and his fellow Spanish explorers "discovered" Sanibel Island while searching for the legendary fountain of youth. They found instead an advanced Calusa Indian culture with settlements that extended from Charlotte Harbor on the mainland to points 30 miles south.

The Calusas believed themselves to be part of the earth and lived within the supportive capabilities of their natural environment. Their life-style was simple: shells and other natural materials were used for construction purposes and weaponry.

In low-lying areas, the Calusas elevated their structures with piles of shells for protection against high storm water as well as from enemies. (Figure 2) The shell mounds often extended into the open waterways and were interlaced with elaborate systems of channels and basins. The huts often were perched on pilings along the sides of these channels. When the channels filled with silt they were allowed to become gardens or rainwater basins, and other mounds were built to provide new channels. The maximum population of the island was approximately 200 Calusas living in 35 huts.[1]

Calusa warriors waged furious battles against Ponce de Leon, De Soto, Menendez, and other explorers who dropped anchor near Sanibel. In 1521, Ponce de Leon died of wounds inflicted by the Calusas during his return to Florida with colonists to begin settlements. Over the years the Calusa culture slowly disintegrated; following the passage of the Indian Removal Act in 1832, the remaining Calusas were confined to reservations.

In the mid-16th century, Spanish pirates were headquartered on Sanibel and her sister island, Captiva. Black Caesar, a henchman of Florida's notorious Gasparilla, operated from Point Ybel, the present location of the Sanibel lighthouse.

After extensive exploration and surveying, Sanibel Island was purchased in 1831 by the Florida Peninsular Land Company (a group of New York investors) as a settlement

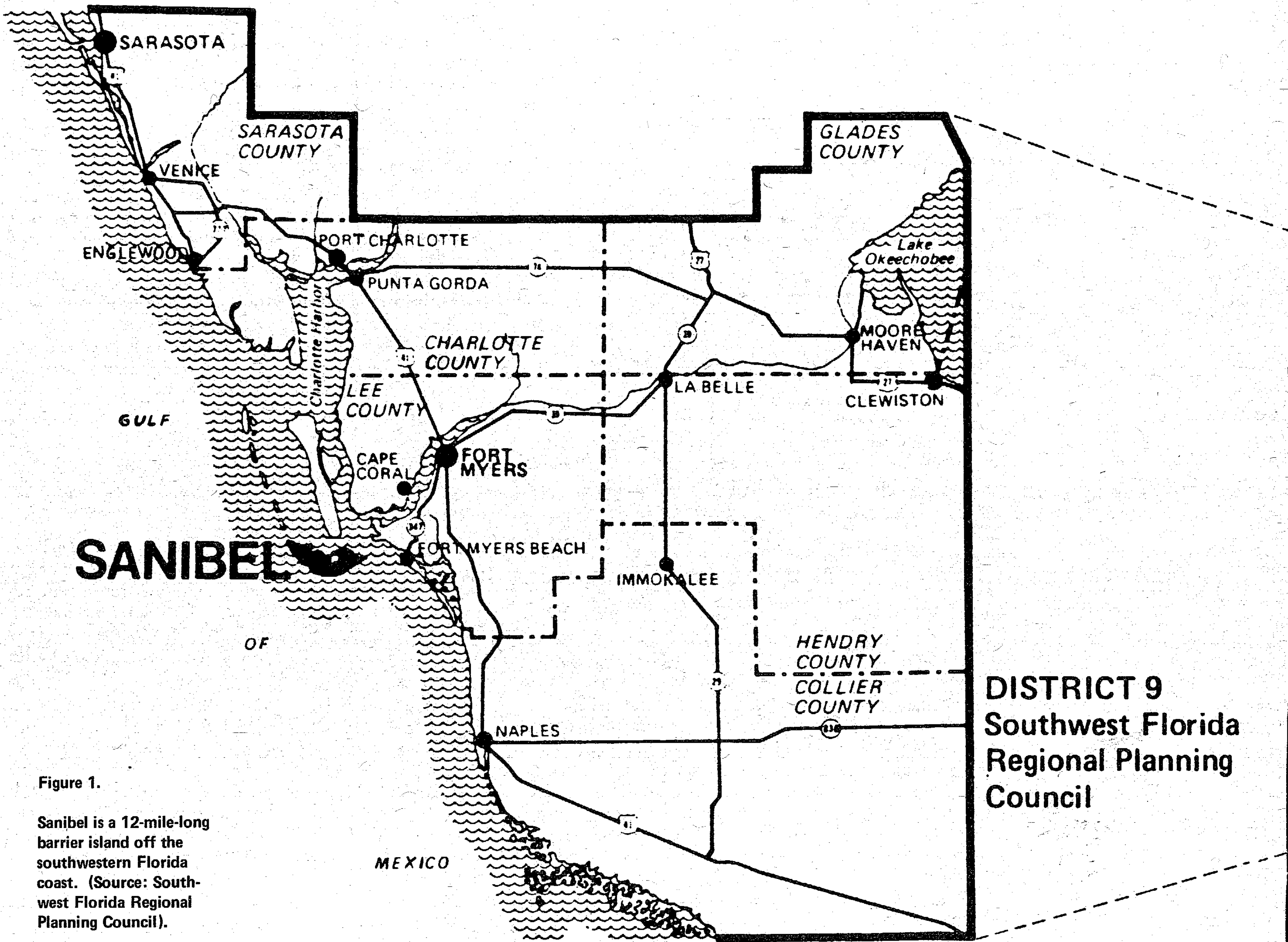
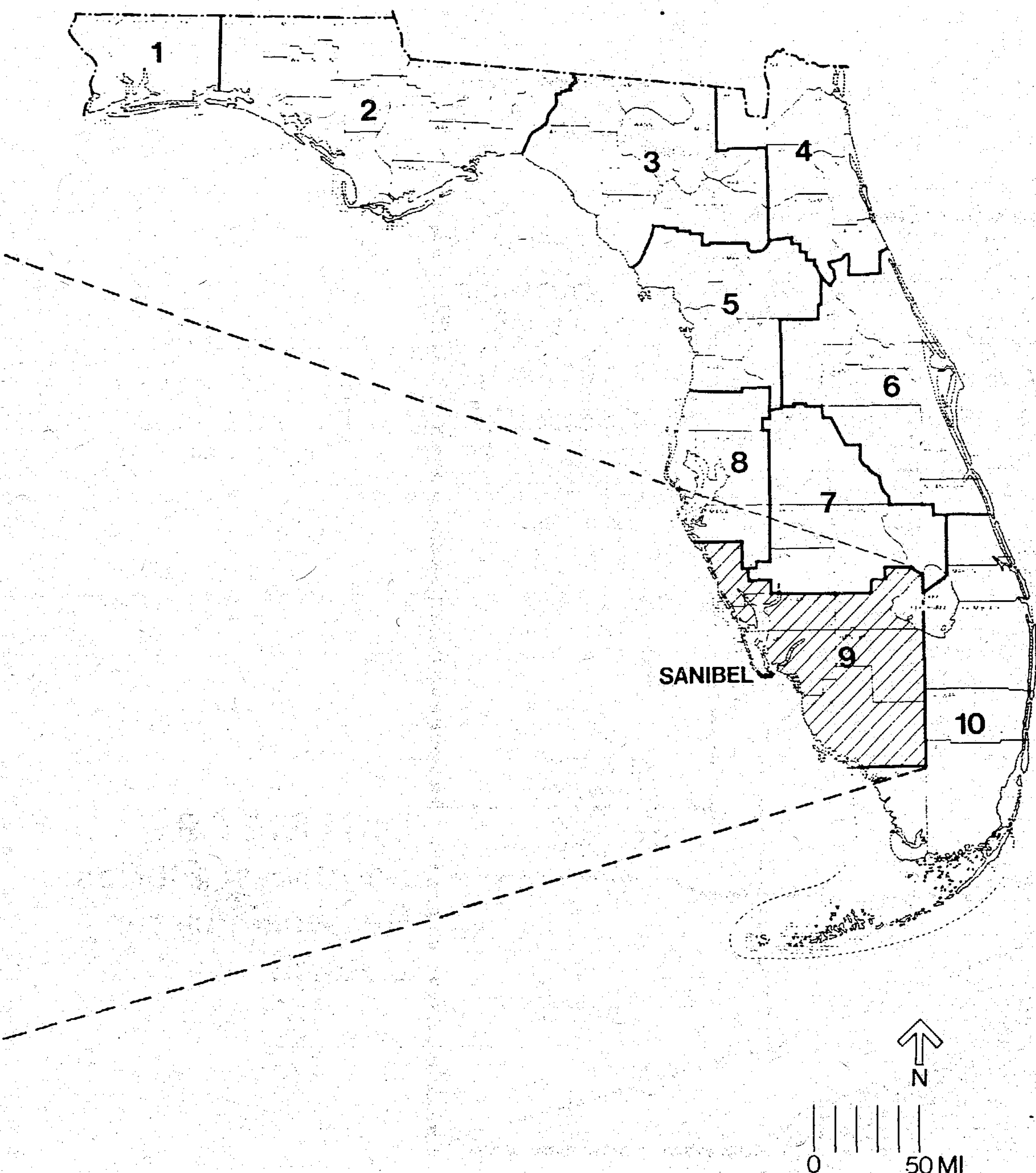


Figure 1.

Sanibel is a 12-mile-long barrier island off the southwestern Florida coast. (Source: Southwest Florida Regional Planning Council).



site because of its good harbor, climate, and general amenities. The first settlers, who arrived in 1833, lived temporarily in palmetto-thatched huts with floors of shell and sand. These early settlers envisioned the island as a paradise for recreation and health recuperation.

When the settlers arrived, the shell ridges on the island were six to eight feet above bay level and the beach was narrow. The mangrove forest along the western shore provided the major source of wood. The interior was a grassy plain, dotted with palmettos, so level that one could see for miles. There were ducks, turkeys, flamingos, curlews, and deer in abundance. The fruits and vegetables harvested by the settlers were of superior quality, and led to expectations that the island would be a profitable agricultural area.

But the settlement did not prosper. Most of the settlers deserted; many left because of a final series of Indian raids in 1836. In 1850, Fort Casey was erected on the site of a former settlement. A hurricane destroyed much of the fort on October 6, 1873.

In 1883, Sanibel Island became a government lighthouse reservation. On August 20, 1884, the lighthouse was activated and run by various family lighthouse keepers until 1949 when the responsibilities were turned over to the Coast Guard Light Attendant Station.

On July 3, 1888, most of Sanibel, except for land around the lighthouse and a small portion of the west end of the island, was released for homesteading. Resettlement began, and with it came Sanibel's first wave of tourists. Sanibel and Captiva attracted such prestigious sightseers as Theodore Roosevelt, Edna St. Vincent Millay, and Charles and Anne Lindbergh. Another famous tourist, Thomas Edison, had once been night watchman for the International Ocean Telegraph Company on Sanibel.

Seashells, sport fishing, and wildlife became Sanibel's principal attractions. The island quickly developed into a favorite vacation site for wildlife conservationists, naturalists, and birdwatchers. Individuals and organized groups visited Sanibel to study the island's bird life and ecology. Despite a series of severe hurricanes (in 1894, 1910, 1921, and 1926), Sanibel's tourist economy prospered.

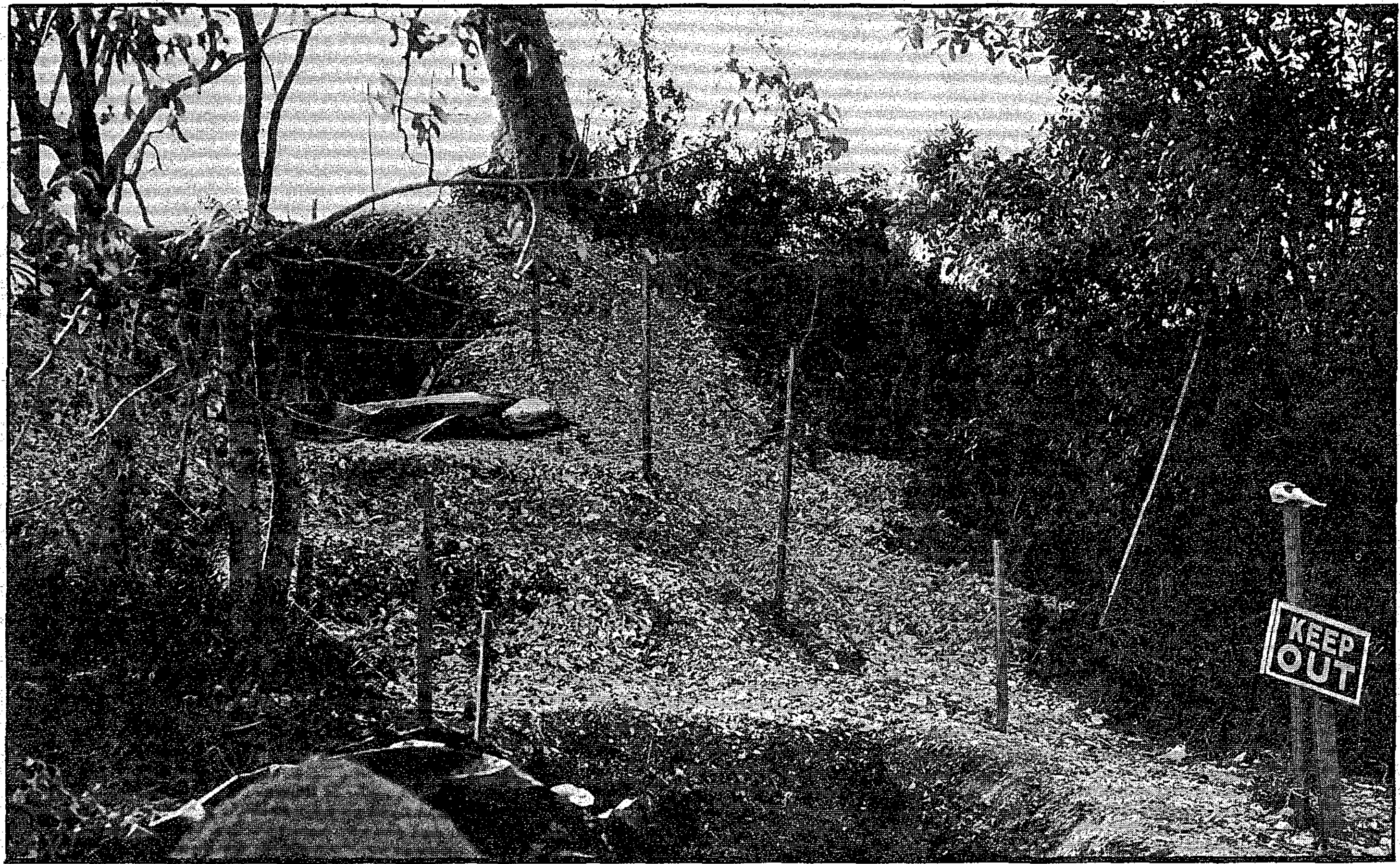


Figure 2.

Calusa Indians built shell mounds on Sanibel to elevate their huts above storm tides.

Recent History

Agricultural development on Sanibel started about 1883 and over the next 40 years encompassed most of the island's arable land. (Figure 4) The major agricultural products were citrus fuits and vegetables such as tomatoes, squash, and eggplants. Severe hurricanes, with accompanying flood tides ranging from 9 to 13 feet, effectively ended farming on Sanibel. The last major storm, in 1926, flooded the entire island with salt water. The 1926 hurricane left financial ruin in its wake, forcing almost half of the island's residents—including most farmers—to leave. The remainder stayed to serve winter visitors and tourists.

In 1926, residents organized the Sanibel Community Association. The association began a campaign to protect a "treasured" island. Jay Norwood ("Ding") Darling, an ardent and articulate defender of wildlife and the natural environment, spearheaded the group's activities and acted as spokesman in Washington and Tallahassee.

Little growth occurred between 1927 and 1944 (the year-round population was about 100), except for a gradual increase in the number of visitors and development of cottages along the gulf coast.[2] In the 1950's, however, Sanibel's reputation for shell collecting and abundant wildlife induced a new surge of tourism and a parallel growth in residences and services. The last and most significant spurt of growth began with completion of the causeway in 1963, and continued until 1974 when the new city government intervened with a general moratorium on new building permits. (Figure 7 and Table 2)

The J.N. "Ding" Darling National Wildlife Refuge (established on October 31, 1945) is closely tied to the history of the conservation movement on Sanibel Island. Darling first came to Captiva Island in 1936 while serving as the head of the U.S. Bureau of Biological Survey (later to become the Fish and Wildlife Service) under Franklin D. Roosevelt. He was taken with the natural values of the islands, and made personal, continued efforts to conserve Sanibel and Captiva for their unique environments and wildlife. Darling became a leader of the Izaak Walton League, was founder of the National Wildlife Federation, and served on the National Audubon Society's board of directors.

The refuge boundary encompasses approximately 4,700 acres of waterways, mangrove forests, and upland. The refuge brings a vast number of tourists to Sanibel. In 1975, more than 1,000,000 tourists visited the island, more than 800,000 of whom visited the refuge. The refuge is the home of more than 267 species of birds, including the great white heron, mottled duck, roseate spoonbill, white and wood ibis, the mangrove cuckoo, and the grey kingbird.

Alligators and otter are year-round residents. The loggerhead sea turtle visits in late spring and summer to breed. More than 400 varieties of seashells can be found on the Sanibel beaches. And snook, redfish, trout, and tarpon provide excellent sportfishing.

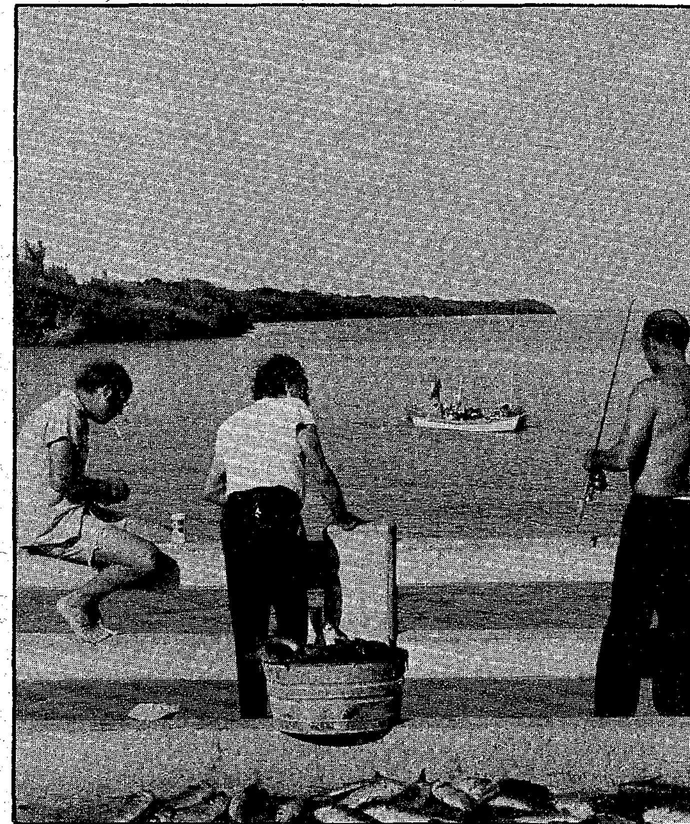


Figure 3.

Saltwater fishing is one of the island's major recreational activities.

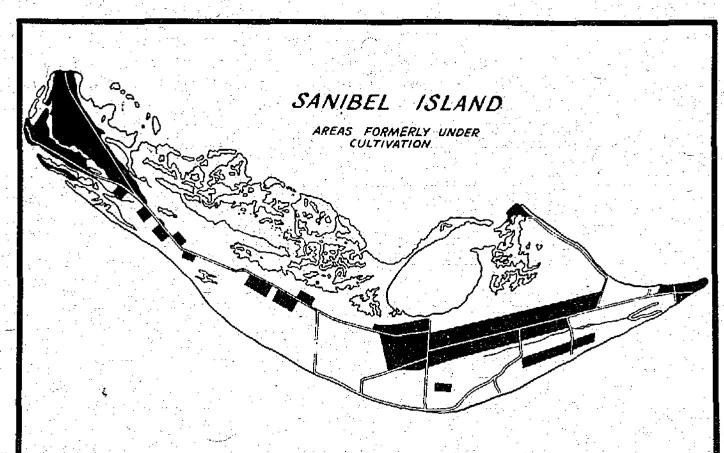


Figure 4.

Areas of Sanibel Island under cultivation before the 1926 hurricane. (Source : Cooley)

Today, the population of Sanibel at mid-winter peak season is about 12,000. It is overwhelmingly white (about 50 blacks live on Sanibel) and predominantly wealthy. The 1970 census figures show that 45.9 percent of the island residents had yearly incomes in excess of $15,000.[3]

The population increase in recent years is due generally to the influx of retired persons, aged 60 and over. In 1970, approximately 36 percent of the population was in this category. The retired population, whether year-round or part-time, takes an active interest in the island's civic affairs and provides the driving force for a wide array of community organizations and programs.

Figure 5.

In 1944, Sanibel Island was relatively unchanged from its original state. (U.S. Department of Agriculture airphoto)

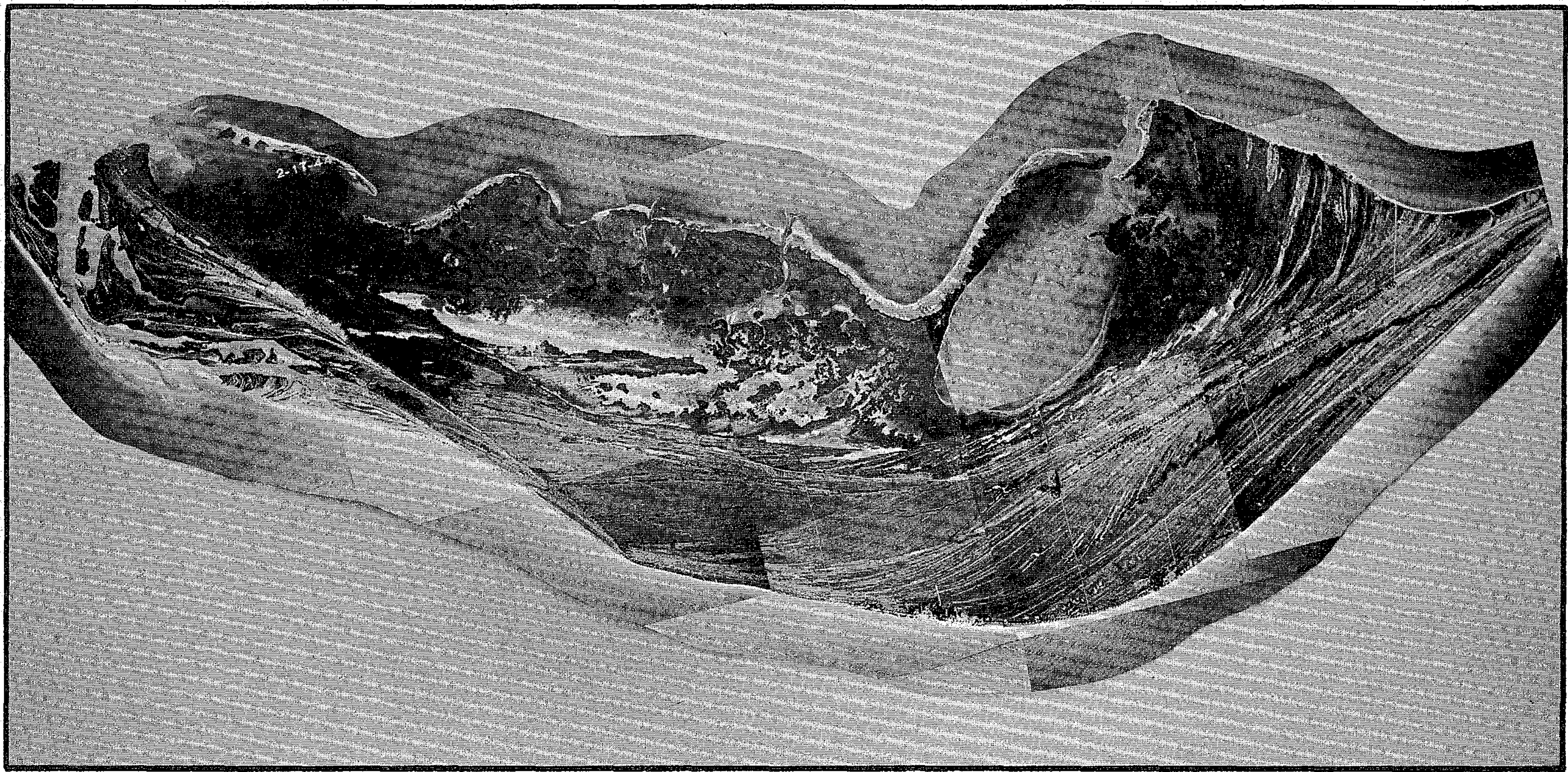


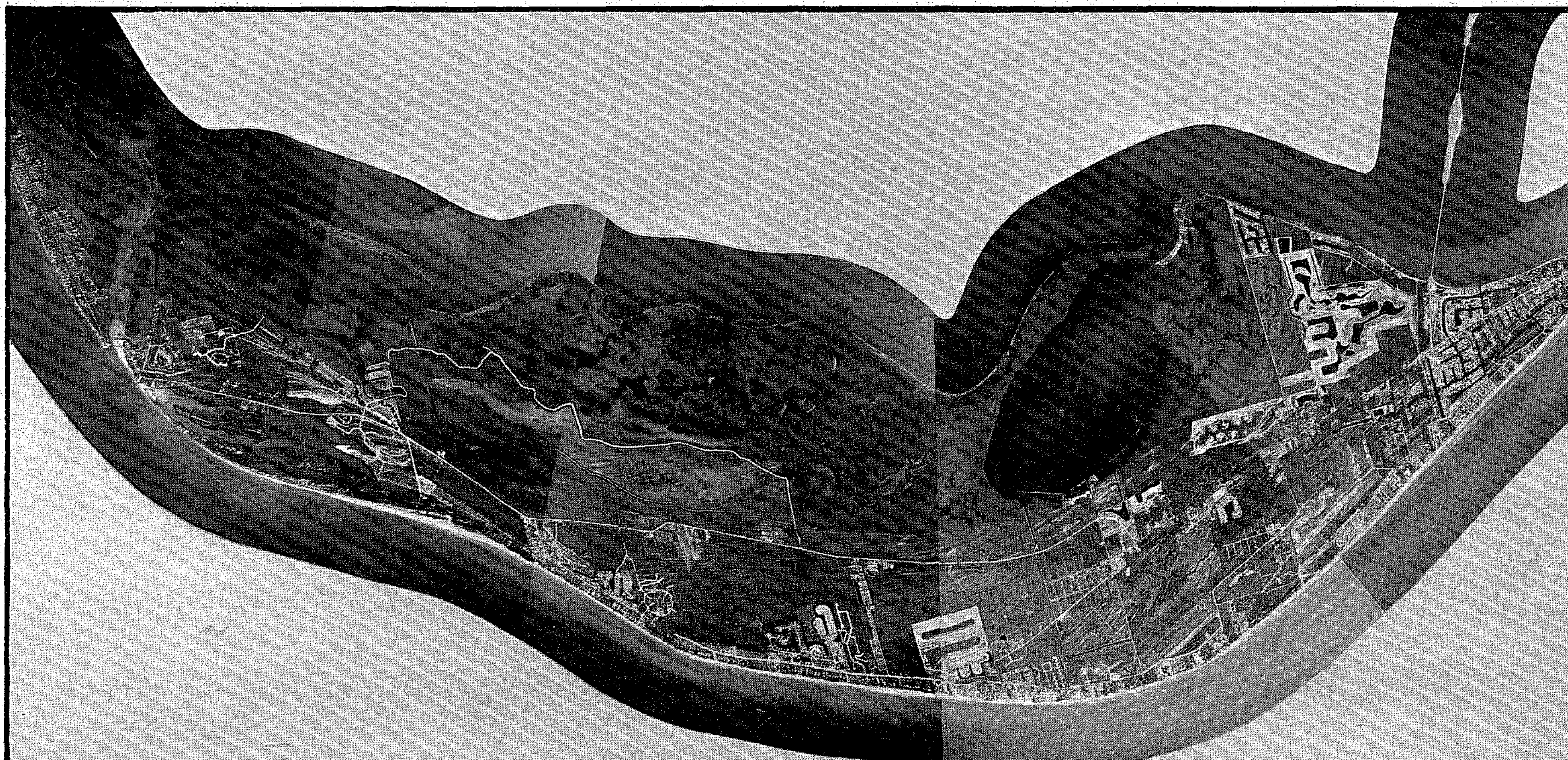
Table 1.

Land use in acres, 1944 and 1975 (U.S. Department of Agriculture)

1944		1975	
3,588	interior	2,393	interior
3,200	mangrove	2,800	mangrove
6,788	total wetlands	5,193	total wetlands
10,730	total island	10,730	total islands
−6788	total wetlands	−5,193	total wetlands
3,942	total upland	5,537	total upland undeveloped and developed area

Figure 6.

By 1975, Sanibel had undergone drastic changes — roads, homesites, canals, artificial lakes, and filled wetlands are apparent in this aerial photograph. (U.S. Department of Agriculture airphoto)



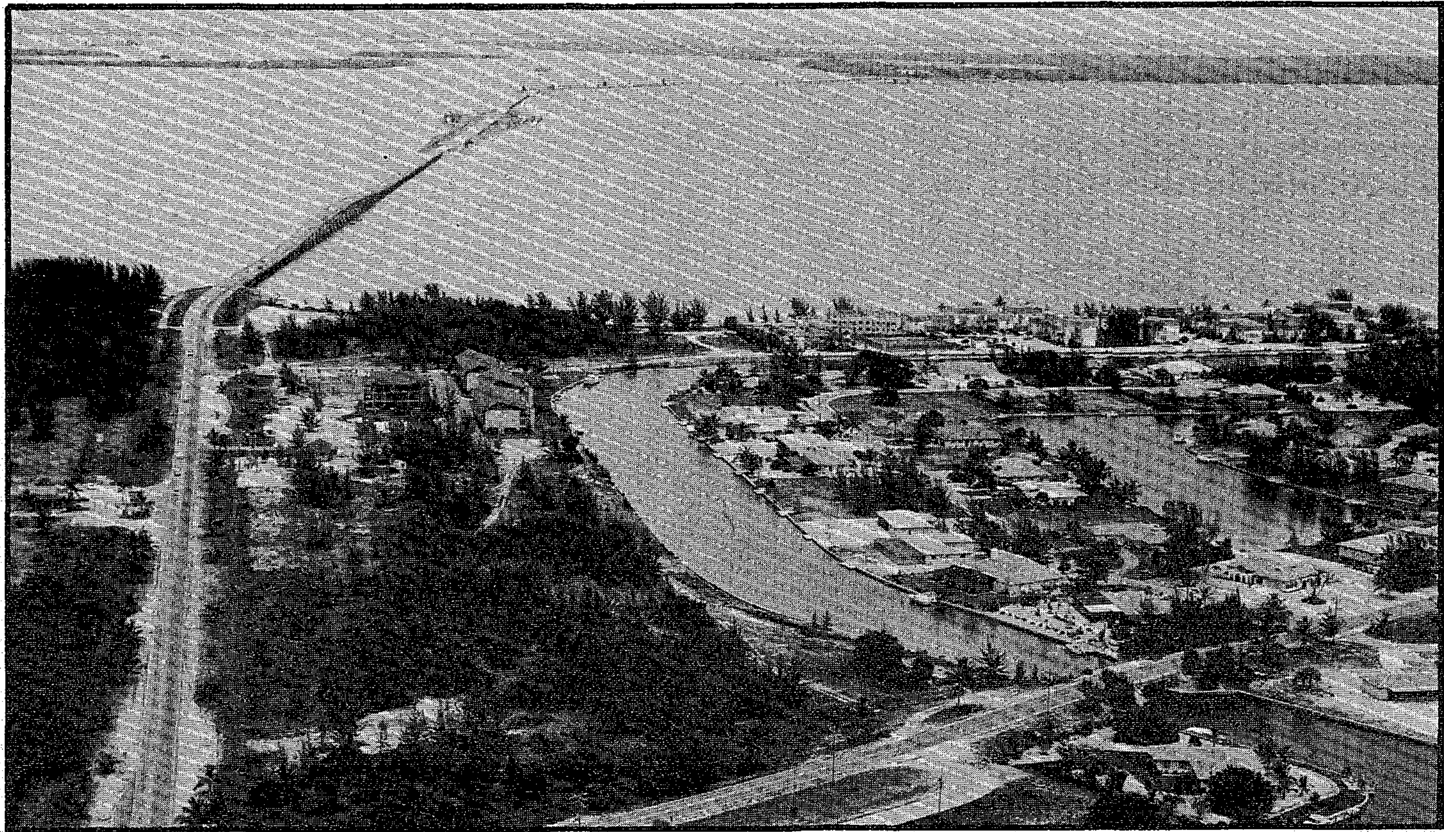


Figure 7.

The completion of the causeway in 1963 between Sanibel and the mainland precipitated a building boom which led to ten years of ecological devastation to the island.

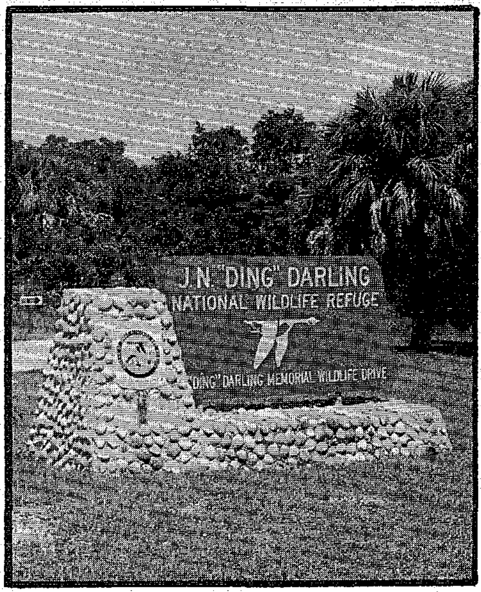


Figure 8.

The J.N. "Ding" Darling National Wildlife Refuge attracts more than 800,000 visitors every year.

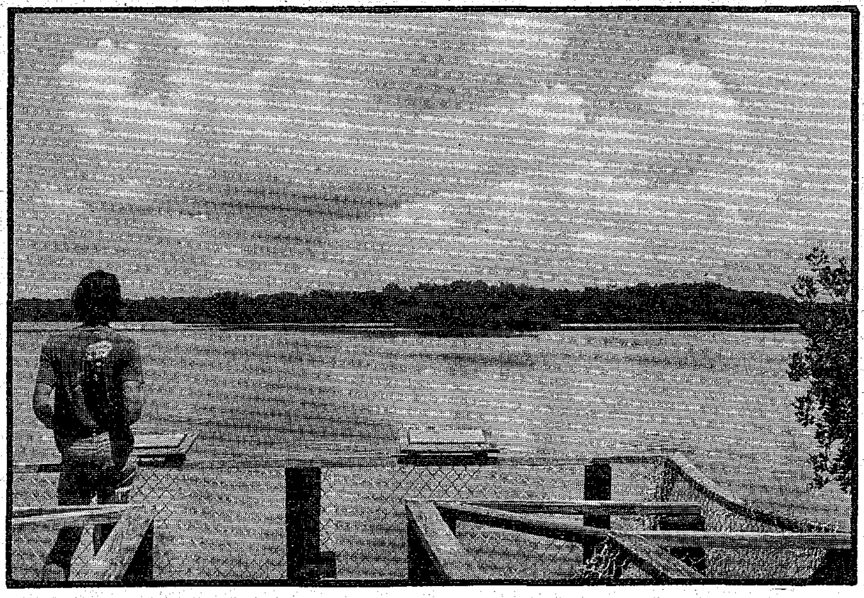


Figure 9.

Overlooks highlight the driving tour trail in the wildlife refuge.

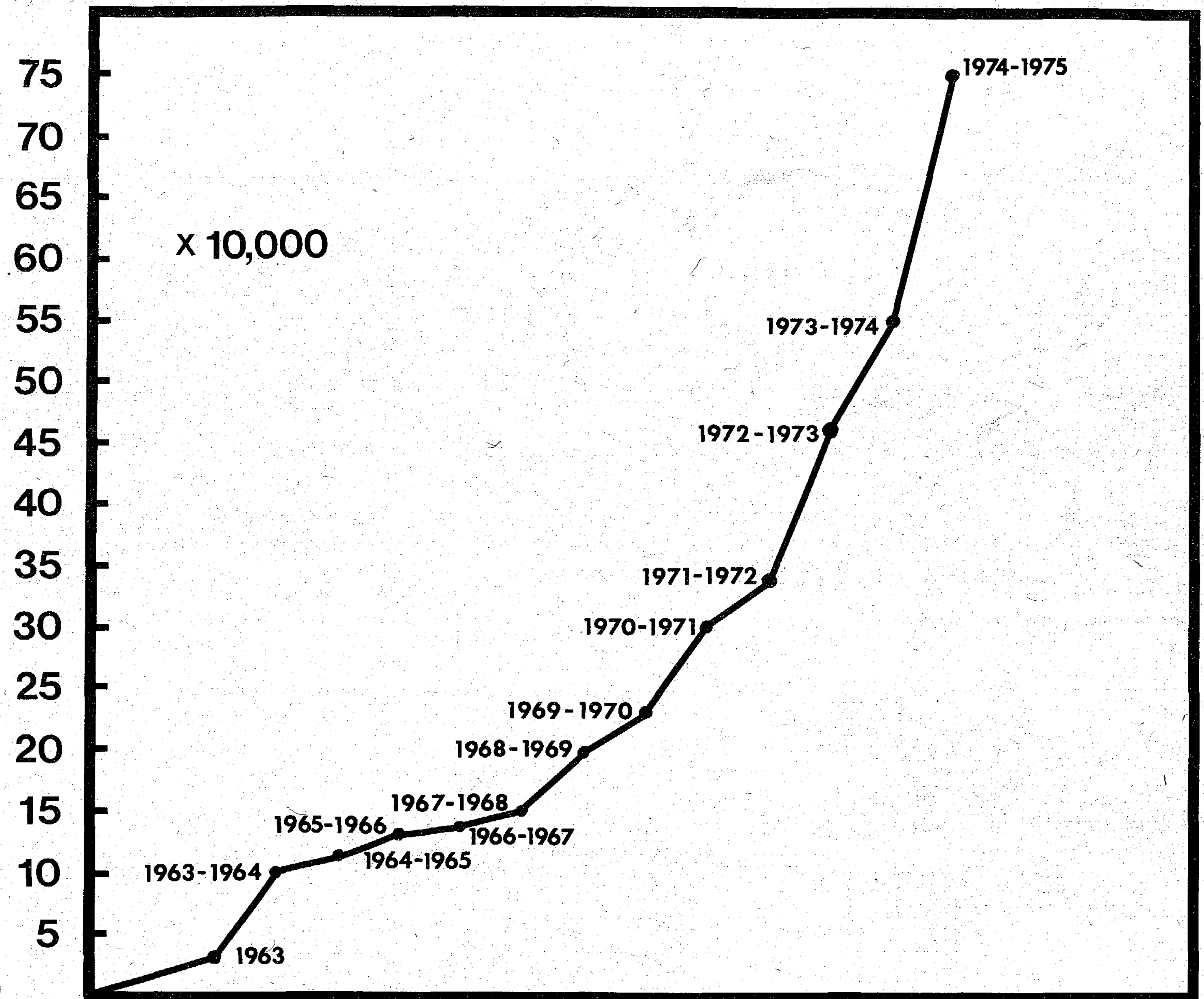


Table 2.

A seven-fold increase in yearly traffic over the new causeway demonstrates the rapid growth of the Sanibel community. (The years given cover a 12-month period from May to April.) (Source: Island Reporter)

Development Problems

There is little question that the completion of the causeway in 1963 exacerbated Sanibel's development problems and led to its incorporation as a city. This highway connection to the mainland provided easy, direct automobile access to the island and precipitated a boom in residential development which ferry service could not have supported. An appeal for contributions to fight the Sanibel bridge and causeway was made, and letters were sent to newspapers and to the State Improvement Fund protesting "the giving of 1,026 acres of Bay bottom fishing grounds to the county commissioners for right-of-way purposes for the Punta Rassa-Sanibel causeway."[4] Other objections cited were adverse changes of water flow and destruction of the scallop bed off Pine Island (both of which actually occurred after construction). Court actions were brought on January 30, 1961, but in July the state's high court upheld the bond issue. Construction began in January 1962.

The three-mile causeway (built by Lee County with a bond issue of $3.9 million) was officially opened on May 26, 1963. It laid the foundation for increasing concern by islanders for the future of their environment. Within a few months of the opening of the causeway, the right of Sanibel's existing independent zoning authority (created by act of the Florida Legislature in 1959) was successfully challenged in court. Islanders were left with no control over the extensive growth which was to result. In 1967, Sanibel-Captiva islanders began strong efforts to preserve and protect the character of the islands and their surrounding waters. The sequence of significant events from 1967 to enactment of the moratorium on new building permits on December 16, 1974, is given in the following chronology.

1967: Sanibel and Captiva Island citizens and civic groups successfully opposed a proposal for a large trailer park on Sanibel, claiming adverse impact on wildlife and overcrowded conditions on the island. The Lee County Commission hired consultants to develop a countywide comprehensive land-use plan to include Sanibel and Captiva Islands.[5]

1968: County planning consultants recommended Sanibel and Captiva for intensive-use, high-density urban development. Included was a four-lane expressway which would bisect the wildlife refuge. These recommendations were successfully opposed by Sanibel-Captiva residents and civic organizations. Nevertheless, the islands were zoned for high-density development and increased business and commercial use. The islanders were able to prevent some

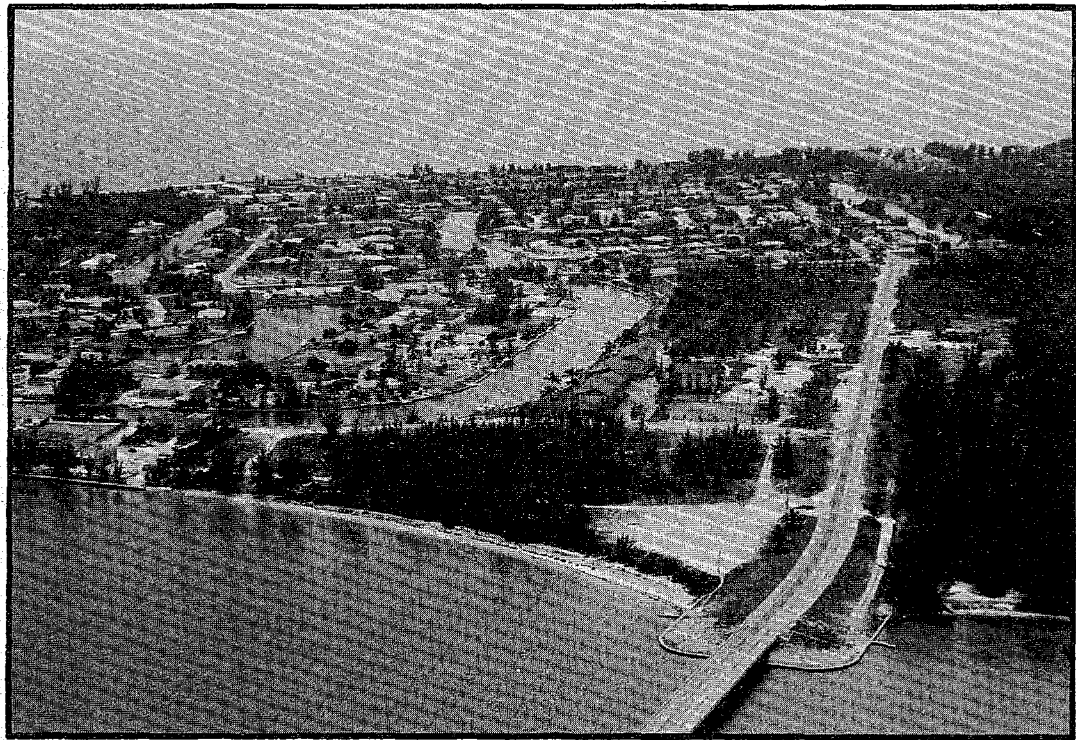


Figure 10.

Large water birds such as this egret populate the wildlife refuge and other parts of Sanibel.

Figure 11.

Zoning of the land near the causeway landfall was an important issue in 1969.

unfavorable zoning, however, and began petitioning Lee County for the passage of a 35-foot height limitation for buildings on Sanibel.[6]

1969: The Sanibel Island Planning Board, an independent citizen organization, successfully opposed a request to Lee County for industrial zoning on Sanibel Island. Sanibel residents worked out a solution for the rezoning of 90 acres of land near the causeway entrance. (Figure 11)

1970: A temporary (six-month) building height limit of 35 feet for Sanibel and Captiva Islands was passed in April by the Lee County Commission with the encouragement of the Captiva Civic Association, Sanibel Community Association, Sanibel-Captiva Chamber of Commerce, Audubon Society, and Sanibel-Captiva Conservation Foundation, with 90 percent of the "freeholders" in the islands in favor. Opposition consisted of the Fort Myers Board of Realtors, Jamestown-Beachview, Inc., and the Captiva Island Company.[7]

In October, the county extended the 35-foot limit to January 15, 1971. The Sanibel-Captiva Planning and Zoning Board studied all zoning requests for island properties and commented on them to the County Zoning Board and commissioners.

1971: The Sanibel-Captiva Planning Board succeeded in having a permanent height limitation ordinance passed by the county. However, an accompanying ordinance for low-density construction and a 100-foot beach setback line was not approved.

Figure 12.

In 1973, protection of the interior wetlands and water basins was a major goal of Sanibel citizens.

In June, the county commissioners established a Sanibel-Captiva Planning Committee to formulate a comprehensive proposal for designation of the islands as areas of environmental concern with comprehensive zoning and land-use provisions. The cooperative island-county committee was composed of two Lee County commissioners, two members of the Sanibel-Captiva Planning Board, one member from the Sanibel Community Association, one member from the Sanibel-Captiva Chamber of Commerce, and one member from the U.S. Fish and Wildlife Service.[8]

In July, the county adopted an interim density limit of 18 apartment units or 22 motel units per acre.

1972: Considerable effort was spent during the year on the planning process. In December, a series of public hearings on the comprehensive land-use plan was held and the plan was modified by the Sanibel-Captiva Planning Committee. The plan called for a population ceiling of about 41,000 persons and provided for no more than 14,852 housing units. It recognized the inevitability of substantial growth over present levels. (In March 1975, the Sanibel Planning Commission reported there were 4,250 housing units on the island). It was, however, a far cry from the population densities anticipated by the Lee County Planning Commission. County zoning ordinances then in effect would have permitted housing for a population of up to 90,000.

1973: Construction on Sanibel and Captiva Islands increased by 72 percent over 1972. The intense development began to tax public sewerage and water supply systems. Freshwater rivers were filled in and mangroves obliterated. Digging for real estate lakes caused intrusion of salt water into freshwater rivers and the sewerage problems were perceived as a threat to the public health of the islanders.[9]

Lee County established a county planning commission in the spring of 1973 and hired a qualified planner and a staff. The planner was relieved of duties in August and the delayed Sanibel-Captiva plan was activated in September but quickly halted by court action requiring it to be part of a county-wide plan. The island's civic groups requested a building moratorium until this plan could be implemented.

The voters rejected Lee County's proposal for sewer districts on Sanibel-Captiva because it was considered to be ill-suited for the island's needs.

The Incorporation Campaign

Failing to convince Lee County of the merits of more strictly controlled development, the Sanibel-Captiva Planning Board next considered home rule. The board conducted a study of the pros and cons of incorporation and the cost of city government. The board also conducted a "straw vote" of island residents which showed that incorporation sentiment was favorable.

A town meeting called by an ad hoc "Commission of Five" was attended by 300 residents who generally supported initiating a study of the merits of home rule and other alternatives for self-government. It was decided not to include Captiva in home-rule attempts because of the need for county support of beach erosion protection.

A new group called the Sanibel Home Rule Study Group (a nonprofit corporation) was created in November 1973. By December, the decision to seriously consider incorporation had been made and funds were raised to hire an expert to explore the island's alternatives. At this point, Lee County hired a new county planner.

The framework for the new city was designed, a draft charter prepared, and public meetings held to discuss the implications of this move. In March 1974, residents met at the Sanibel Community Association to vote on placing an incorporation referendum on the ballot. By a vote of 436 to 358 the referendum gained a place on the November ballot.

The proposed new charter called for a five-person city council, elected to four-year terms, and for a city manager. The new city would have zoning power and the authority to develop and implement a land-use plan that controlled growth and preserved environmental values. The incorporation proposal included the right to:

1) create a new zoning ordinance consistent with the special needs of the island;
2) develop a master plan guaranteeing orderly growth and protection of the environment, and
3) set and enforce density ratios, height restrictions on buildings, and setback lines from the beaches.[10]

The dominant theme of the incorporation campaign was the need to secure stronger local control over decisions concerning land use on the island. The study group disbanded and a new organization, Sanibel Tomorrow, was formed to promote passage of the referendum. In addition, a group called Save our Sanibel (SOS) was formed to publicize the struggle for incorporation nationally.

The principal opposition was led by members of the Chamber of Commerce who formed an Action Committee. The Chamber of Commerce itself was divided over incorporation, the most vehement opposition coming from land developers and builders. Attempts were made to block approval of the new charter in the state legislature and in the courts, and to dissuade citizens from voting for incorporation. A new Florida law, the County Powers Act (which permitted counties to tax unincorporated areas for "municipal purposes"), sidetracked the cost-of-government issue which was expected initially to be a major factor in the campaign. Under the act, Sanibel would have had its taxes increased by the county to pay for municipal services if it had not incorporated.

Sanibel Island represented a rich tax base for Lee County and served as a symbol of development prosperity.

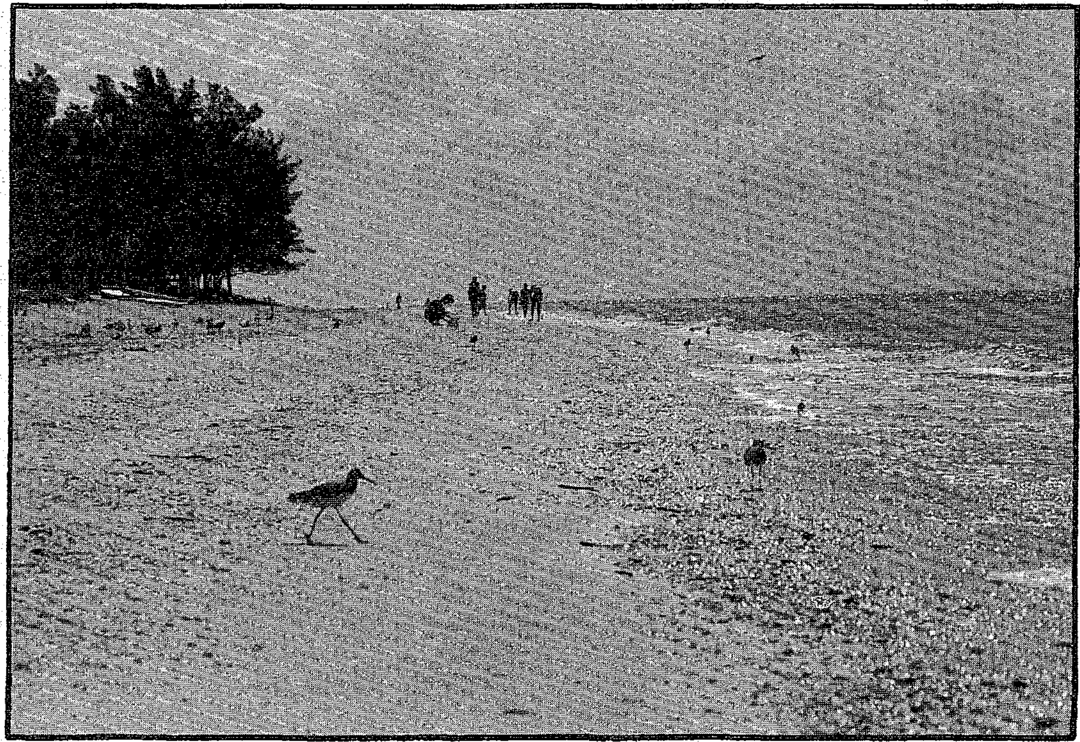


Figure 13.

The experience gained in protecting Sanibel's beaches, waters, and living resources readily applies to other barrier islands.

Through 1974, Sanibel transactions had been accounting for 40 percent of the county's condominium sales. The real estate tax base for Sanibel for 1975 was $104.5 million."[11] During the legislative process for incorporation, the chairman of the Lee County Commission and one commissioner wrote to Sanibel residents to dissuade them from home rule. The county cooperated with the Sanibel-Captiva Chamber of Commerce to work against incorporation.

On November 5, 1974, 85 percent of the Sanibel voters turned out to register their views on the incorporation proposal. The vote was 689 to 394 in favor of the referendum. A month later, the five-member City Council was elected by the voters, and Porter Goss was elected mayor by the council. The councilmen included two members of the Chamber of Commerce's Action Committee, the chairman of Sanibel Tomorrow, Inc., the former president of the Sanibel-Captiva Planning Board, Inc., and the president of Caretta Research (a nonprofit group established to foster research on loggerhead turtles, genus *Caretta*).

On December 16, 1974, the government of the City of Sanibel officially took office and began the administration of the island as an independent municipality. The new government immediately passed several resolutions which became effective upon passage. No new building permits or zoning changes were to be issued for at least 90 days, or until a comprehensive land-use plan was adopted. Only those builders who had received permits before the incorporation vote and who had actually broken ground within 60 days thereafter were allowed to continue construction. A flood of new building permits issued by Lee County in the interim between the referendum and December 16 (42 in all, totalling $9,618,400 in construction costs) prevented the halting of all new development—but the intensive development problem had been somewhat alleviated.[12]

Planning

Because the Sanibel City Council was elected to control growth on the island through the development of a reasonable land-use plan, replanning became a top priority item for the new government.

Early in 1975, the Sanibel Planning Commission developed specifications for a new land-use plan and began the process of selecting a planning consultant.

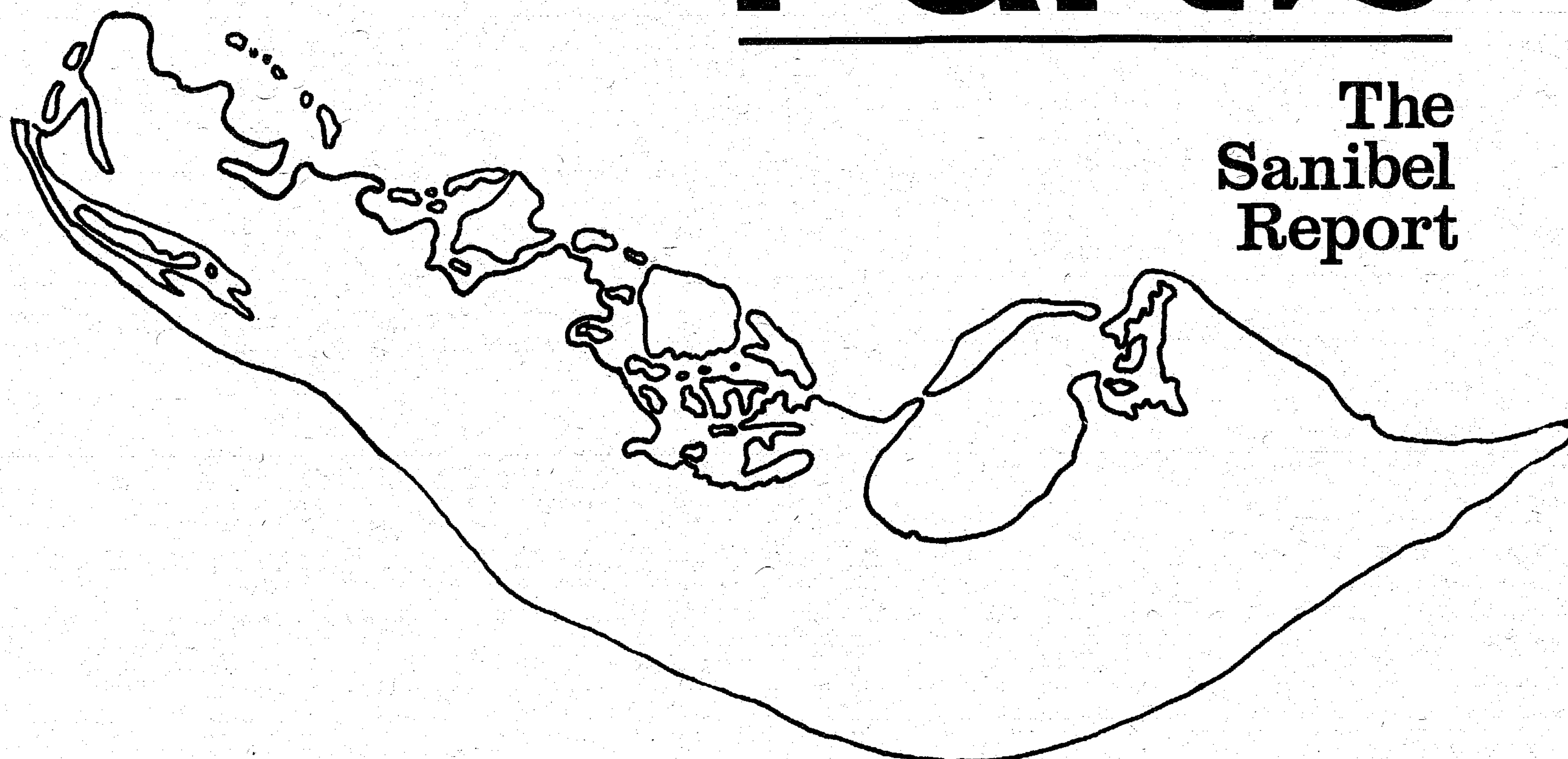
In April, the City Council selected as planning consultants the firm of Wallace, McHarg, Roberts and Todd (WMRT). WMRT was asked to design the plan and "recommend zoning code and zoning map, building regulations or codes and subdivisions, and other pertinent land-use regulations." The planning consultant also was responsible for receiving public input through interviews and workshops with "representative groups." In addition, WMRT coordinated and received assistance from the community through 10 task force committees, appointed by the Planning Commission.

Concurrently, citizen organizations searched for an organization that could assist the city by providing a detailed description of the natural systems of Sanibel, and by suggesting means for conservation of natural resources and natural systems. The Conservation Foundation was selected, and in March a campaign was initiated by the Sanibel-Captiva Conservation Foundation to raise funds from charitable organizations for its work. In May, initial funding became available and work began. The natural systems study was designed both to provide information useful to the city and to test a planning approach that could be instructive to Florida and to the nation regarding local implementation of coastal zone management and, in particular, barrier island resources management. The results of the natural systems study are presented in the chapters that follow.

The Natural Systems Study

Part 2

The Sanibel Report



Part II of the book presents The Conservation Foundation's natural systems study and the major results for each of four elements: 1) analysis of the island's ecosystem; 2) identification of the principal ecological zones; 3) diagnosis of the condition of these zones; and 4) suggestions for management requirements to conserve the island's natural systems and resources. The chapters in this section are organized along those lines—the identification, condition, and management recommendations are given separately for each ecological zone. Because subsurface hydrology spans all zones on the island and, in fact, determines the characteristics of each zone, it is dealt with separately and presented first.

The Natural Systems Study Process: The Conservation Foundation engaged a team of experts to assist with its carrying-capacity assessment and formulation of conservation requirements. The experts furnished individual reports that were integrated into a program of environmental management specifications. In addition to a variety of consulting specialists, The Conservation Foundation team included staff experts in law, planning, ecology, economics, and administration.

The Conservation Foundation (CF) began its natural systems study in May 1975.

As the study progressed through the summer, CF made the data collections, draft consultant reports, and preliminary findings available to the Sanibel-Captiva Conservation Foundation (SCCF), the citizens of Sanibel, the Planning Commission, and the planning consultants, Wallace, McHarg, Roberts and Todd (WMRT). Some results, however, were available as early as June.

CF's basic task was to develop principles and requirements for future development which could prevent damage to the remaining natural systems, and principles and requirements for restoration of past damage to the natural systems.

It must be stressed that the management program resulting from these recommendations was designed to attain maximum protection and perpetuation of the natural systems of the island, particularly through optimization of the basic water systems that govern their health. CF realized that other planning policies developed by the city could impose constraints on development in addition to those we suggested, or that, conversely, the optimum development pattern for the island might require modification of certain of the natural systems protection measures suggested.

Data Collection, Analysis, and Formulation of Requirements: The basic approach to the natural systems study was, first, to formulate a data collection plan from a preliminary survey of Sanibel and from existing knowledge of the ecosystem and natural resources; and second, to divide up the necessary work along disciplinary lines (hydrology, botany, wildlife biology, etc.) for assignment to survey teams. To assist these teams in coordinating their

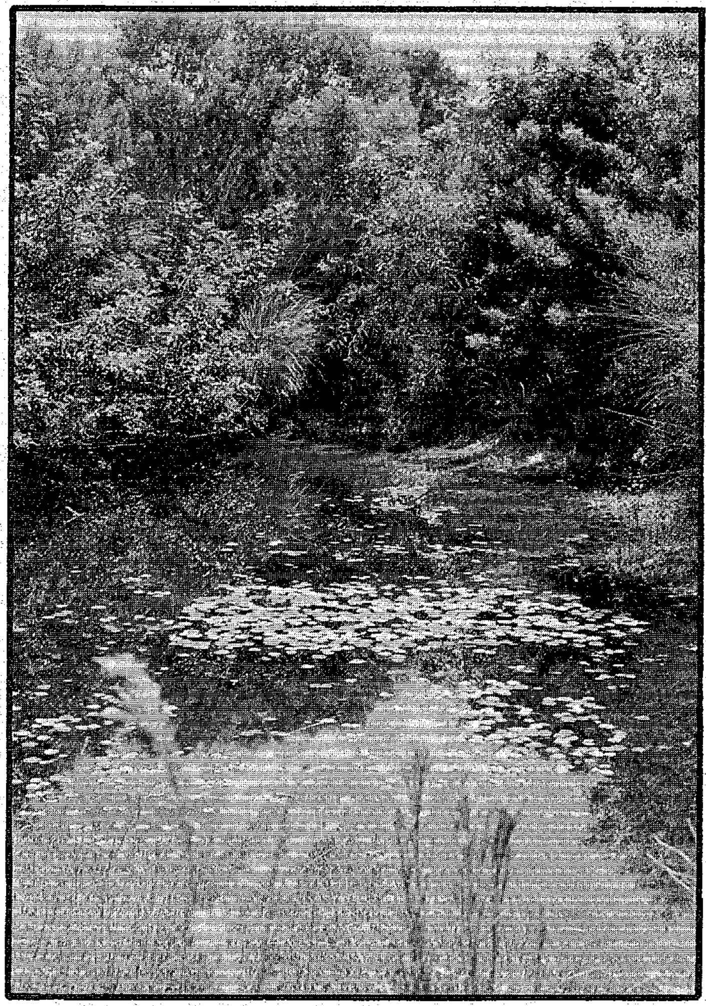


Figure 14.

Preservation of the island's various water systems is essential to maintenance of its overall ecosystem.

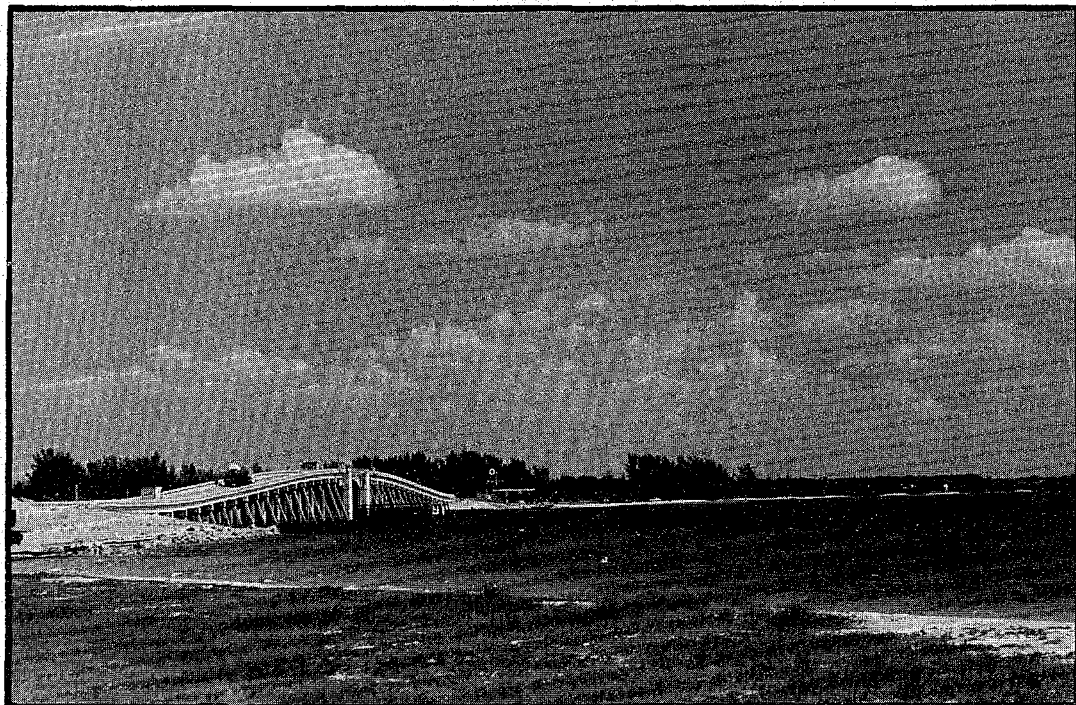


Figure 15.
Sections of the road on the mainland end of the Sanibel causeway are so low that they can flood completely before hurricane evacuation begins, thus blocking all escaping traffic.

efforts and in clarifying and reevaluating their work plans, The Conservation Foundation organized workshops, held informal meetings, circulated relevant progress information, and encouraged direct communication between participants. Altogether, 18 technical consultants were involved, along with a panel of special technical advisors.

The six principal natural systems reports produced by the consultant teams are included as an appendix. The subjects covered are hydrology, vegetation, beach geology, wildlife ecology, estuarine ecology, and the natural energy system.

In addition to these systems reports, a number of data base reports were produced. The data base reports are not included in this document, but copies are available from The Conservation Foundation. They include the following six subjects: plant survey, by Taylor Alexander; reptiles, amphibians, and mammals, by George R. Campbell; water quality and wetlands management and performance data for sewage plants, by Albert L. Veri and Langdon Warner; the pollutant-loading capacity of the interior wetlands, by G. Kenneth Young; water quality, by Thomas Missimer; and birds, by Oliver Hewitt.

Both WMRT and CF gave first priority to identifying and classifying the subsystems of the Sanibel ecosystem. (Tables 3, 4) These subsystems, termed "ecological zones" in the plan, were described in initial maps of zones prepared by CF in June and July 1975. With modifications and refinements by WMRT and the Planning Commission these zones furnished the basis for the permitted uses, density limits, and performance standards contained in the Sanibel Plan.

The various water-related aspects of the Sanibel Plan demonstrate that successful protection of the Sanibel environment depends primarily on proper water management (insect control, for example, is included in the plan's water-related section because water management is the key to success in combating mosquitoes, the major insect pest on Sanibel).

Restoring and conserving the island's water system require actions both by the public and private sectors. On the public side, substantial capital outlays as well as moderate operational costs are required for improvements. Control of private development is also essential, and many of CF's recommendations were so oriented.

The major natural hazard affecting occupation of Sanibel is the tropical hurricane. Sanibel shares with all other barrier islands of the Atlantic and Gulf of Mexico extreme vulnerability to hurricanes. Evacuation is the major defense. The rate at which automobile traffic can move over the causeway to the mainland limits the speed of evacuation and imposes a limit on population and therefore on residential density. (Figure 15) Regarding potential threats to life and property, wildfires are much less a problem than hurricanes; actually, they may have a strong beneficial effect on the interior wetlands ecological zone.

Both permitted uses and residential density limits in the Sanibel Plan are governed by a set of regulations—or performance standards—that control the design and construction of residential development. In their absence, density allocations would have to be reduced to provide for the conservation of natural systems and natural resources. Recognizing that Sanibel is composed of several different zones with particular characteristics and varying tolerances, a separate set of standards is applied to each zone.

	GULF BEACH (FRONT BEACH / BACK BEACH)	GULF BEACH RIDGE	INTERIOR WETLAND BASIN (UPLAND / LOWLAND / UPLAND)	MID-ISLAND RIDGES
	The Gulf Beach Zone includes the area between the state setback line and the city boundary 300′ offshore. There are two subareas within this zone—the Front Beach and the Back Beach. The Front Beach extends from the city limit to Mean High Water. Sand in this subarea is in constant motion. Sand migrates between the berm and offshore bars and is transported by long-shore currents. The Back Beach comprises that area between Mean High Water and the the state setback line. Sand in this subarea is moved by wind and water and stabilized by vegetation, forming low dunes.	The Gulf Beach Ridge Zone is the major ridge immediately behind the beach. It is stabilized by dense vegetation. Blind Pass—a subarea within this zone—is of very recent formation and susceptible to dramatic change.	The Interior Wetland Basin Zone is the interior bowl which serves as a fresh water reservoir. It is composed of parallel systems of ridges and swales with corresponding bands of vegetation. There are two sub-areas within this zone — lowland and upland. The lowland area is composed of low ridges and wide swales and experiences extended periods of flooding each year. The upland consists of higher, broader ridges and narrower swales, and is characterized by less frequent flooding and more upland vegetation types.	The Mid-Island Ridges Zone comprises the major ridges along the central axis of the Island and includes the highest elevations. In most areas this zone divides the Bay-Mangrove watershed from the Interior Wetlands watershed.
CLIMATE	Salt Spray			Salt Spray
GEOLOGY	Oxidized barrier sands and shells			
SUBSURFACE HYDROLOGY	Saline Shallow Aquifer	Fresh Water Table Aquifer	Fresh Water Table Aquifer	Fresh Water Table Aquifer
SURFACE HYDROLOGY	Mean High Water 10 Year Storm Flooding (Front Beach); 10 Year Storm Flooding (Back Beach) 25 Year Storm Flooding		Seasonal High Water Table at Surface (Lowland) Seasonally Flooded 10 Year Storm Flooding	Seasonally Flooded 10 Year Storm Flooding
SOILS	Oxidized Barrier Sands and Shells	Thin Organics	Organics over Sand Marl	Thin Organics
VEGETATION	Widely scattered herbaceous vegetation and shrubs. Sea Oats, railroad vine, sea spurges, beach plum, sea purslane, bay cedar, yucca, salt bush. Invasion of Australian Pine.	Sea grape, yucca, bay cedar, saltbush, marsh elder, cabbage palmetto, wax myrtle, coconut palm. Invasion of Australian Pine.	Vegetation varies according to elevation and water levels. Swales: Cordgrass, sawgrass, andropogon, water hyssop, buttonwood, cattails, spatterdock, hydrilla, chara, duckweed, wigeongrass. Low ridges: Marsh elder, leather fern, wax myrtle, cabbage palmetto. Invasion of Brazilian pepper and Australian Pine.	West Indian Flora, Cabbage palmetto, saw palmetto, seagrape, gumbo limbo, Jamaica dogwood, Florida privat, wild lime, strangler fig, wild coffee, myrsine, joewood, wax myrtle, sea oxeye, poison ivy, Virginia creeper, prickly pear cactus, bowstring hemp, century plant. Invasion of Australian Pine, Brazilian pepper, and cajeput.
WILDLIFE	Loggerhead Turtle, Bottle-nosed Dolphin, Otter, Manatee, Brown Pelican, Snowy Egret, Red-breasted Merganser, American Oystercatcher, Semipalmated Plover, Piping Plover, Snowy Plover, Wilson's Plover, Black-bellied Plover, Ruddy Turnstone, Willet, Knot, Least Sandpiper, Dunlin, Semipalmated Sandpiper, Western Sandpiper, Sanderling, Herring Gulf, Ringbilled Gull, Laughing Gull, Forster's Tern, Least Tern, Royal Tern, Sandwich Tern, Caspian Tern, Black Skimmer.	Box Turtle, Gopher Tortoise, Green Anole, Key West Anole, Five-lined Skink, Six-lined Racerunner, Mangrove Watersnake, Black Racer, Indigo Snake, Coral Snake, Southern Toad, Green Treefrog, Squirrel Treefrog, Bobwhite, Smooth-billed Ani, Red-bellied Woodpecker, Great Crested Flycatcher, Purple Martin, Fish Crow, Starling, White-eyed Vireo, Prairie Warbler, House Sparrow, Cardinal.	American Alligator, Box Turtle, Chicken Turtle, Soft Shell Turtle, Green Anole, Key West Anole, Five-lined Skink, Florida Watersnake, Ribbon Snake, Southern Toad, Green Treefrog, Squirrel Treefrog, Southern Leopard Frog, Pig Frog, Opossum, Armadillo, Marsh Rabbit, Sanibel Rice Rat, Sanibel Cotton Rat, Raccoon, Otter, Florida Bobcat, Pied-billed Grebe, Anhinga, Least Bittern, Mottled Duck, Blue-winged Teal, King Rail, Virginia Rail, Sora, Common Gallinule, Killdeer, Spotted Sandpiper, Common Snipe, Belted Kingfisher, Long-billed Marsh Wren, Swamp Sparrow.	Gopher Tortoise, Green Anole, Key West Anole, Five-lined Skink, Six-lined Racerunner, Black Racer, Indigo Snake, Coral Snake, Diamondback Rattlesnake, Southern Toad, Green Treefrog, Squirrel Treefrog, Opossum, Armadillo, Marsh Rabbit, Sanibel Rice Rat, Sanibel Cotton Rat, Florida Panther, Florida Bobcat, Bobwhite, Smooth-villed Ani, Red-bellied Woodpecker, Great Crested Flycatcher, Purple Martin, Fish Crow, Starling, White-eyed Vireo, Prairie Warbler, House Sparrow, Cardinal.

Table 3.

Sanibel's major ecological zones as interpreted by Wallace, McHarg, Roberts and Todd.

MANGROVES (MANGROVES / TIDAL FLATS / MANGROVES)	BAY BEACH
The Mangrove Zone includes all areas of red, black and white mangroves, as well as the tidal flats and hardwood hammocks within them. Much of this zone, including all areas of red mangrove, is subject to daily tidal flooding. Other areas of the zone are subject to extended periods of flooding every year.	The Bay Beach Zone extends from the city's boundary 300' into the bay to a setback line approximately 100' behind the Mean High Water Line. It is a lower energy beach than the Gulf Beach, and includes areas of marine grasses on the bay bottom. It includes both sand beach and mud beach.
CLIMATE	**CLIMATE**
GEOLOGY Oxidized Barrier Sands and Shells	**GEOLOGY** Muds, Organic Materials, Sands and Shells
SUBSURFACE HYDROLOGY	**SUBSURFACE HYDROLOGY** Saline Shallow Aquifer
SURFACE HYDROLOGY Mean High Water	**SURFACE HYDROLOGY** 10 Year Storm Flooding; 25 Year Storm Flooding
SOILS Peat Deposits Salt Flats	**SOILS** Muds, Organic Materials, Sands and Shells
VEGETATION Mostly mangroves with hardwoods at higher elevations. Vegetation responds to elevation and tidal patterns. Red mangroves predominate to the mean high tide line, black mangroves predominate to slightly higher elevations above the mean high tide line. Red mangrove, black mangrove, white mangrove, buttonwood. Seagrape, gumbo limbo, palmetto	**VEGETATION** Sand beach: Sea oats, railroad vine, sea spurges, beach plum, sea purslane, bay cedar, yucca, salt bush. Invasion of Australian Pine Mud beach: Red mangroves Submerged beach: Marine grasses
WILDLIFE American Alligator, Green Anole, Mangrove Watersnake, Marsh Rabbit, Otter, Florida Panther, Manatee, Bottle-nosed Dolphin, Brown Pelican, Double-crested Cormorant, Great Blue Heron, Green Heron, Snowy Egret, Louisiana Heron, Little Blue Heron, Black-crowned Night Heron, Yellow-crowned Night Heron, White Ibis, Roseate Spoonbill, Lesser Scaup Duck, Red-breasted Merganser, Bald Eagle, Osprey, Clapper Rail, American Oystercatcher, Piping Plover, Snowy Plover, Wilson's Plover, Blackbellied Plover, Ruddy Turnstone, Eastern Willet, Laughing Gull, Least Tern, Black Skimmer.	**WILDLIFE** Loggerhead Turtle, Bottle-nosed Dolphin, Otter, Manatee, Brown Pelican, Snowy Egret, Red-breasted Merganser, American Oystercatcher, Semipalmated Plover, Piping Plover, Snowy Plover, Wilson's Plover, Black-bellied Plover, Ruddy Turnstone, Willet, Knot, Least Sandpiper, Dunlin, Semipalmated Sandpiper, Western Sandpiper, Sanderling, Herring Gull, Ringbilled Gull, Laughing Gull, Forster's Tern, Least Tern, Royal Tern, Sandwich Tern, Caspian Tern, Black Skimmer.

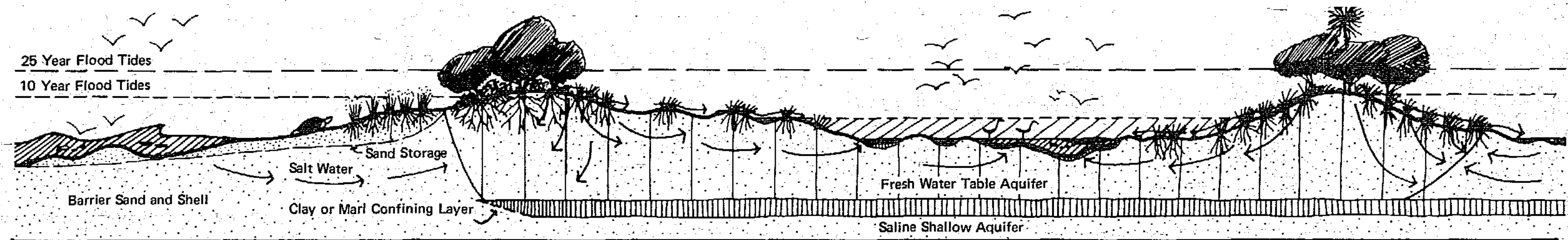
These standards incorporate a number of the requirements recommended by CF.

Each type of residential development has the potential for a particular combination of environmental disturbances. The amount of natural systems damage that may result from any disturbance depends upon the characteristics and vulnerabilities of the specific subsystem involved. Protection of the three water-based ecologic subsystems must also include controls on the fourth subsystem, the uplands, particularly on land modification activities associated with site preparation for development. The necessary constraints may have to encourage, and in some cases require, adjustment of traditional Florida standards of residential density, project design, site preparation, drainage, and other performance factors.

The development requirements recommended by CF can be administered conveniently through the city's site plan review process. Well-conceived standards can implement the specific environmental objectives set out in regulations and also provide equity and predictability for developers in the approval process.

There is a second important requirement for a comprehensive environmental program for Sanibel—restoration, the repair of existing damage to the natural systems. The major elements of the recommended program are: water level restoration and flood control in the interior wetlands basin; drainage restoration in the mangroves; vegetation restoration in all four subsystems; and beach profile restoration.

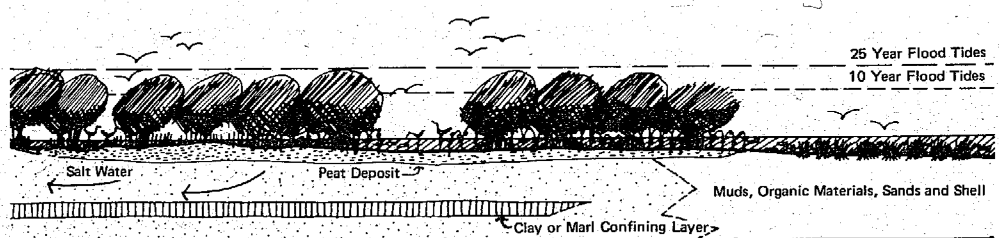
The Consensus Method: In conducting the natural systems study our consulting experts not only performed the surveys and determined the condition of the systems, they also identified management requirements and formulated recommendations. In order to reach a consensus on requirements and recommendations, the following procedure was devised: 1) Survey team members were consulted by CF staff members during the course of their work; 2) working conclusions were transmitted to the team by CF; 3) a draft of conclusions based upon the comments was prepared; 4) a final workshop was held to refine and consolidate the requirements and recommendations; 5) a revised draft was sent to the team members; and 6) a formal, preliminary set of recommendations—based upon



GULF BEACH		GULF BEACH RIDGE	INTERIOR WETLAND BASIN			MID-ISLAND RIDGES
FRONT BEACH	BACK BEACH		UPLAND	LOWLAND	UPLAND	
The Gulf Beach Zone includes the area between the state setback line and the city boundary 300' offshore. There are two subareas within this zone—the Front Beach and the Back Beach. The Front Beach extends from the city limit to Mean High Water. Sand in this subarea is in constant motion. Sand migrates between the berm and offshore bars and is transported by longshore currents. The Back Beach comprises that area between Mean High Water and the state setback line. Sand in this subarea is moved by wind and water and stabilized by vegetation, forming low dunes. **FUNCTIONS** Storm Protection Shoreline Stabilization Maintenance of Marine Life Maintenance of Wildlife The Gulf Beach Zone is the Island's first defense in storm and flood when the impact of storm waves erodes the sand reservoir in the berm. The low dunes of the Back Beach are a reservoir of sand which may be eroded after the berm in a severe storm, thus protecting property further inland on the Beach Ridge. The natural profile of the Gulf Beach Zone is a response to processes of wind, currents, and waves. Undistrubed, it is in a state of balance with natural forces, thus "stabilizing" the shoreline. The Front Beach supports the marine life for which Sanibel is famous, and is an important feeding area for island wildlife. The low dunes of the Back Beach are an important nesting area for wildlife, the loggerhead turtle being a prime example. **ELEMENTS ESSENTIAL TO FUNCTIONS** Storm Protection and Shoreline Stabilization: —Natural profile of beach —Sand reservoir in berm, bars and dunes —Gradual and dispersed runoff from land —Longshore sand movement —Hardy dune vegetation Maintenance of Marine Life —Access to beach —Good water quality Maintenance of Island Wildlife —Access to beach —Good water quality —Abundant marine life		The Gulf Beach Ridge Zone is the major ridge immediately behind the beach. It is stabilized by dense vegetation. Blind Pass—a subarea within this zone—is of very recent formation and susceptible to dramatic change. **FUNCTIONS** Storm Protection Flood Protection Shoreline Stabliization Maintenance of Water Quality Maintenance of Fresh Water System The Gulf Beach Ridge is a dike which buffers flood tides and storm winds, prevents increased flooding in the interior (unless overtopped by waves) and contributes to shoreline stabilization. Water quality is maintained by the filtering function of soil and vegetation. Much fresh water runoff enters the ground in the Gulf Beach Ridge Zone, halting inward intrusion of salt water from the Gulf and thus maintaining the extent of the fresh water lens. **ELEMENTS ESSENTIAL TO FUNCTIONS** Storm Protection and Shoreline Stabilization: —Shoreline stabilization and storm protection functions of the Gulf Beach Zone —Natural configuration and elevation of ridge —well established hardy vegetation Maintenance of Water Quality —Gradual and dispersed runoff —Filtration of runoff through vegetation and soil Maintenance of Fresh Water System: —Recharge of runoff to fresh water lens —Drainage of runoff to interior wetland —Aquiclude between shallow saline aquifer and fresh water lens.	The Interior Wetland Basin Zone is the interior bowl which serves as a fresh water reservoir. It is composed of parallel systems of ridges and swales with corresponding bands of vegetation. There are two sub-areas within this zone—lowland and upland. The lowland area is composed of low ridges and wide swales and experiences extended periods of flooding each year. The upland consists of higher, broader ridges and narrower swales, and is characterized by less frequent flooding and more upland vegetation types. **FUNCTIONS** Flood Protection Maintenance of Water Quality Maintenance of Fresh Water System Maintenance of Island Wildlife Since the elevation of the Interior Wetland Basin is lower than the adjacent zones, it serves as a storage area for flood waters until they are absorbed into the aquifer. Water Quality is protected by the filtering function of soil and vegetation. This zone is crucial to the maintenance of the fresh water lens. It also has the capacity to maintain and improve water quality, and provides food, shelter, water, and nesting areas to wildlife, including the American alligator. **ELEMENTS ESSENTIAL TO FUNCTIONS** Flood Protection: —Water storage capacity —Free-flowing water circulation Maintenance of Water Quality —Free-flowing water circulation —Gradual and dispersed runoff —Filtration of runoff through vegetation and soil —Restriction of industrial and domestic wastes discharged into interior wetland —Water quality function of Gulf Beach Ridge and Mid-Island Ridges Zones Maintenance of Fresh Water System: —Recharge of runoff to fresh water lens —Sufficient water levels —Aquiclude between shallow saline aquifer and fresh water lens —Free-flowing water circulation Maintenance of Wildlife: —Good water quality —Fresh water system —Access to water —Native vegetation of value to wildlife			The Mid-Island Ridges Zone comprises the major ridges along the central axis of the Island and includes the highest elevations. In most areas this zone divides the Bay-Mangrove watershed from the Interior Wetlands watershed. **FUNCTIONS** Storm Protection Flood Protection Maintenance of Water Quality Maintenance of Fresh Water System The elevation of the Mid-Island Ridges Zone provides flood protection. This zone helps maintain water quality by the filtering functions of soil and vegetation. Much fresh water runoff enters the ground in the Mid-Island Ridges Zone, halting inward intrusion of salt water from the Bay and thus maintaining the fresh water lens. **ELEMENTS ESSENTIAL TO FUNCTIONS** Flood Protection: —Elevation of ridge Maintenance of Water Quality: —Gradual and dispersed runoff —Filtration of runoff through vegetation and soil Maintenance of Fresh Water System: —Recharge of runoff to fresh water lens —Drainage of runoff to interior wetland —Aquiclude between shallow saline aquifer and fresh water lens —Elevation of ridges

Table 4.

The functions of Sanibel's major ecological zones as interpreted by Wallace, McHarg, Roberts and Todd.



MANGROVES	BAY BEACH
MANGROVES / TIDAL FLATS / MANGROVES	
The Mangrove Zone includes all areas of red, black and white mangroves, as well as the tidal flats and hardwood hammocks within them. Much of this zone, including all areas of red mangrove, is subject to daily tidal flooding. Other areas of the zone are subject to extended periods of flooding every year.	The Bay Beach Zone extends from the city's boundary 300' into the bay to a setback line approximately 100' behind the Mean High Water Line. It is a lower energy beach than the Gulf Beach, and includes areas of marine grasses on the bay bottom. It includes both sand beach and mud beach.
FUNCTIONS Storm Protection Flood Protection Shoreline Stabilization Maintenance of Water Quality Maintenance of Marine Life Maintenance of Wildlife	**FUNCTIONS** Storm Protection Shoreline Stabilization Maintenance of Marine Life Mainteannce of Wildlife
The dense canopy and roots of the mangroves buffer storm winds and tidal surges. The arching prop-roots of the red mangrove and the roots of the black mangrove trap sediments and stabilize and extend the shoreline. Mangroves preserve water quality by filtering suspended material and assimilating dissolved nutrients. Mangroves maintain the highly productive marine ecosystem and provide food, shelter, and nesting areas for wildlife.	The Bay Beach Zone buffers the impact of storm waves. The natural form of the Bay Beach is a response to natural processes of wind, currents, and waves. Undisturbed, it is in a state of balance with natural forces, thus "stabilizing" the shoreline. The Bay Beach is a feeding area for island wildlife. Beds of marine grasses in submerged portions of the beach are important nursery and feeding areas for marine life.
ELEMENTS ESSENTIAL TO FUNCTIONS Storm Protection, Shoreline Stabilization and Land Building: —Healthy mangroves Maintenance of Water Quality: —Healthy mangroves —Restriction of domestic and industrial wastes discharged into Mangrove Zone —Water circulation Maintenance of Marine Life: —Healthy mangroves —Good water quality Maintenance of Island Wildlife: —Healthy mangroves —Abundant marine life	**ELEMENTS ESSENTIAL TO FUNCTIONS** Storm Protection and Shoreline Stabilization: —Natural profile of beach —Gradual and dispersed runoff from land —Longshore sand movement —Hardy beach vegetation Maintenance of Marine Life: —Mangroves —Marine grass beds —Access to beach —Good water quality Maintenance of Wildlife: —Access to beach —Good water quality —Abundant marine life

comments on the revised workshop draft—was prepared for presentation to the City Council on September 16, 1975. The final recommendations included minor revisions in response to additional data or analysis provided by the consultants after September 16.

The consensus method is an efficient and economic way to get a wide spectrum of technical talent to reach recommendations useful to management. Its success is conditioned upon these four requirements: 1) The technical experts must already have experience in their fields of expertise; 2) they must be encouraged to review past literature on the area, to spend time in the field, and to collect such new data as are needed to confirm their general understanding of the system; 3) they must each be required to report in writing on their investigations and findings, and 4) they must be well prepared for decision sessions by receiving, in advance, progress reports of colleagues' work, preliminary findings, and so forth.

Citizen Guidance: An essential element of the study design involved frequent consultation with a panel of Sanibel citizens selected by the project sponsor to ensure that the environmental specifications would be most useful to the community. The aim here was to enrich the process by providing opportunities for early interchange between the natural systems analysts and citizens of the island. This approach provided the opportunity to adjust the program while work was in progress.

The Conservation Foundation team worked closely with its sponsor, the Sanibel-Captiva Conservation Foundation, in structuring the consultations as a series of workshops with the citizen panel. The 13 cooperating panelists were a diverse group of SCCF members. They included a local banker, two land developers, a member of the planning commission, an editor of the local newspaper, and several other citizens.

The workshop series was divided into two sections. The first five sessions focused on providing panelists with the technical information required to make intelligent assessments concerning the environmental needs of the island. The remaining four sessions were devoted to discussions of policy options and the development of environmental criteria with which to evaluate the emerging land-use plan.

The five technical workshops were held in conjunction with the scientists' work on the island. The scientists presented background information at the workshops and discussed with panelists the scientific principles and technical considerations pertinent to the formation of an environmentally sound land-use plan. Each meeting was devoted to a specific environmental discipline: vegetation, birds, hydrology, insect control, and beach erosion.

Following the workshops, three sessions were held to discuss the specific options implicit in the presentations by the scientists. At a fourth and final meeting, CF's initial recommendations were incorporated into a preliminary presentation to the Planning Commission. This presentation was made to the commission at a public meeting in August 1975.

From the beginning it was recognized that a high level of understanding would be required for the panelists to grasp the complex interrelationships among mechanisms which govern natural systems, because this understanding must be achieved if citizens are to make perceptive judgments on issues of environmental importance. Therefore, the panelists were educated in basic natural systems knowledge before their opinions on recommendations were requested. The results indicated that citizens *can* be aroused to participate and learn natural science fundamentals if they believe their contribution can affect the result.

CHAPTER 2

WATER

1. Hydrology

Water is the major factor in all the ecological zones on Sanibel Island. It sets the conditions that distinguish the zones, and it affects the soils, vegetation, and wildlife in each. At the same time, it ties the various zones together through complex changes in flow and water quality. (Figure 16)

Climatic Conditions

Sanibel Island has a subtropic climate with an estimated average temperature of 74°F. An average temperature of 83° occurs during August, and an average of 64° during January.[13] A killing frost takes place every few years.[14]

An easterly wind blows across Sanibel most of the year except during the passing of winter frontal systems and tropical storms.

About 70 percent of the rainfall on Sanibel Island occurs during sporadic thunderstorms throughout the wet season (June through October). The remaining 30 percent falls in the dry season (November through May).[15] Because of the localized nature of thunderstorms, the distribution of rainfall varies considerably across the island, but averages about 42 inches per year.[16]

Hurricanes and other tropical storms sometimes affect Sanibel's hydrologic system. In the past, intense rainfall during hurricanes and tropical storms has caused extensive flooding, and complete tidal overtopping of the island occurred during several severe hurricanes.

Between 1830 and 1968, 23 hurricanes and 23 tropical storms or depressions passed within 50 miles of Lee County.[17] According to Jordan, the probability of a tropical storm or hurricane passing through the Gulf of Mexico is 50 percent for a given season.[18]

Groundwater System

There are at least two *deep artesian aquifers* underlying Sanibel Island that yield significant quantities of water: the Lower Hawthorn aquifer and the Suwannee aquifer. Neither aquifer is directly recharged on the island. The

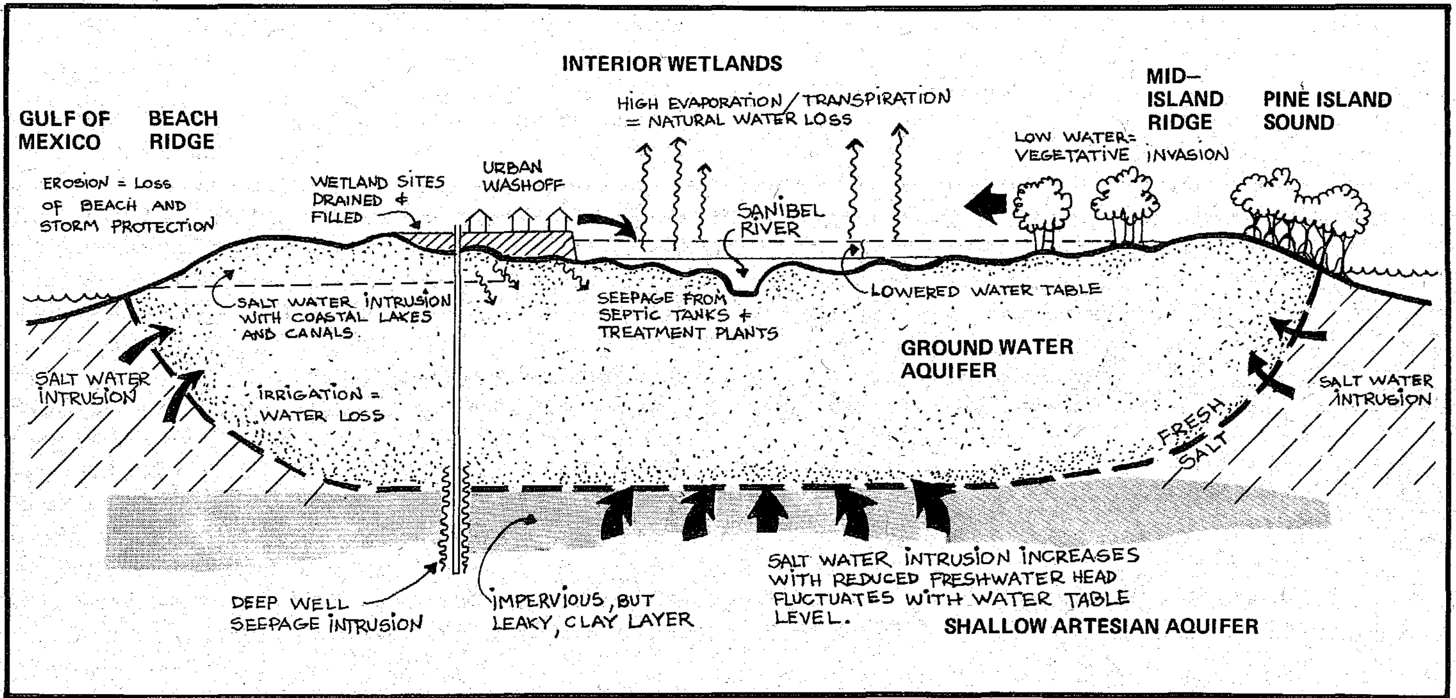


Figure 16.

The ecology of the entire island depends on the healthy functioning of the interior wetlands.

Lower Hawthorn aquifer is positioned near the contact between the Hawthorn Formation and the underlying Tampa Limestone, while the Suwannee aquifer lies near the contact between the Tampa Limestone and the underlying Suwannee Limestone. (Table 5)

Artesian head pressure within these lower aquifers ranges from 16 to 32 feet above mean sea level on the island. The highest head occurs on the eastern part of the island and decreases to the west. Daily fluctuations of 1 to 2 feet occur due to tidal and atmospheric pressure variations.[19]

The Lower Hawthorn and Suwannee aquifers generally contain saline water—or water that has at least 1,000 milligrams per liter (mg/l) of dissolved solids.[20] Vertical change in water quality within the saline-water aquifers is shown in Table 5. The water in the upper part of the Lower Hawthorn aquifer is highly saline. A relatively thin zone of fresh water, containing 600 mg/l to 1,000 mg/l of dissolved chloride, occurs near the base of the lower Hawthorn aquifer. Dissolved chloride concentrations in the Suwannee aquifer are nearly 1,000 mg/l at the top of the aquifer, and increase progressively with depth. Extreme variations of water quality in each aquifer occur from well to well on the island. The freshwater zone occurs at different depth intervals in nearly every well, and sometimes does not occur at all.

Little is known about other characteristics of these aquifers, such as transmissivity, storage coefficient, sustained yield, draw-down, or permanence of quality. Some artesian wells on Sanibel leak, discharging poor quality water into fresher zones.

The top of the *shallow artesian aquifer* occurs between 25 and 30 feet below mean sea level in the Pleistocene Limestone. It is normally separated from the overlying water-table aquifer by a heterogeneous mud stratum, and separated from the lower artesian aquifers by carbonate clay beds in the Tamiami Formation. There are some areas where the upper confining bed is extremely thin, or does not exist. Leakage between the shallow artesian and the water-table aquifers is possible in these areas.

Water levels in the shallow artesian aquifer fluctuate daily with the tides. The range of these fluctuations is a function of the distance to the nearest tidal water body, and the permeability of the aquifer. Water levels in the shallow artesian aquifer are not greatly responsive to seasonal water level variations in the overlying water-table aquifer.

Water quality varies considerably in the shallow artesian aquifer, but the entire aquifer is saline. Chloride values often exceed concentrations in seawater, usually about 19,000 mg/l in the vicinity of Sanibel. These high chloride waters may have formed when the strata were originally deposited, or through downward leakage and selective osmotic differentiation. The lower chloride concentrations may be the result of partial flushing during deposition, or recent flushing.

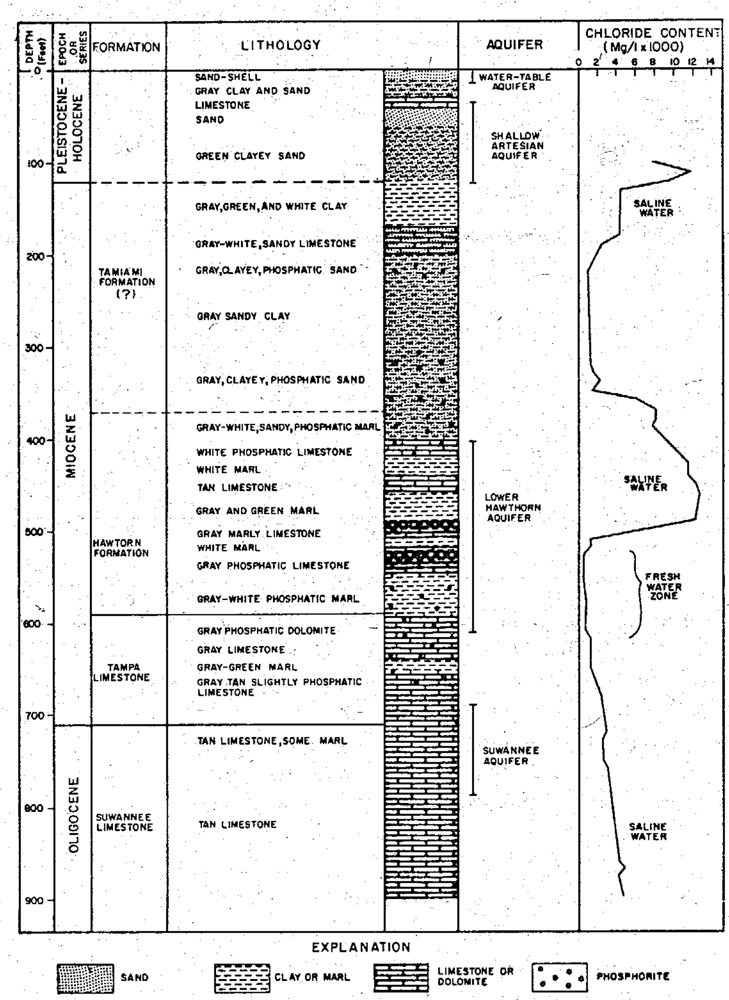


Table 5.

Sanibel Island's subsurface geologic formations, including chloride concentrations in groundwater (from test hole L-193). (Source: D. Boggess)

There is no known recharge to the shallow artesian aquifer other than possible downward leakage, which occurs only under special conditions. Leakage of water between the shallow artesian aquifer and the water-table aquifer is strictly a function of head differential and vertical permeability. During high tide periods, the water level in the shallow artesian aquifer usually stands above the water table, and potential leakage is upward. During the low part of the tidal cycle, the water level in the shallow artesian aquifer usually drops below the water table, and possible leakage is downward. When the water table is high for an extended period, such as after heavy rainfall, the water table may remain above the artesian water level through numerous tidal cycles. To some degree, leakage between the two aquifers occurs continuously. The vertical permeability of the mud stratum is the primary control of the quantity leaked.

The uppermost 20 to 25 feet of sediment on Sanibel Island is unconfined, consisting of quartz sand, shell, and some minor percentages of carbonate mud in the lower beds. The saturated part of this layer is termed the *water-table aquifer*.

Climatic factors primarily control water table fluctuations on Sanibel, with secondary effects caused by man's activities. The water table rises in response to recharge, and declines when water is discharged from the aquifer. The only natural source of freshwater recharge on the island is rainfall. In the absence of freshwater recharge, saline water may recharge the aquifer laterally from the sea, through the surface water system, or from the underlying shallow artesian aquifer. Natural discharge from the aquifer includes evaporation, evapotranspiration, groundwater discharge to the sea, and discharge to streams or lakes. Some recharge to the aquifer results from man's activities, such as inflow from deep artesian wells, inflow of treated sewage effluent, and septic tank discharges. Discharge from the aquifer also has been altered by man. An enhanced surface drainage system now discharges some water to the sea (Figure 17), and a minor amount of water is pumped for irrigation.

When the water table is high on Sanibel, a much greater quantity of fresh water is stored, and the wetland areas are filled with surface water. When the water table is low, the quantity of water in storage decreases and wetland areas tend to dry.

The fresh water stored in the water-table aquifer has a great natural variation in quality. Even small perturbations can result in upward pluming or other saline intrusions, and tidal overtopping sometimes occurs. Without an adequate quantity of fresh water stored within the water-table aquifer, the present flora and fauna on Sanibel Island could not exist.

2. Water Quality

The quality of Sanibel's surface water is substandard. Sewage from 20 package plants and more than 2,000 septic tanks flows through the soil to pollute ground and surface waters. Fertilizers, pesticides, and other pollutants further degrade the water. The water-table aquifer is polluted with salt water.

A heavy influx of nutrient-laden wastewater into the eastern segment of the Sanibel River has caused blooms of undesirable vegetation that have depleted dissolved oxygen. General stagnation and the deposition of organic detritus have caused low values of dissolved oxygen to occur throughout much of the interior drainage system.

Pathogens can exist in untreated or partially treated sewage. Diseases can also originate from protozoan organisms living in sewage. Entero viruses present still another health hazard. Although their presence in sewage does not guarantee an epidemic, they do present a constant threat of infection. The hepatitis virus, for example, which can exist in shellfish living in polluted water, can infect

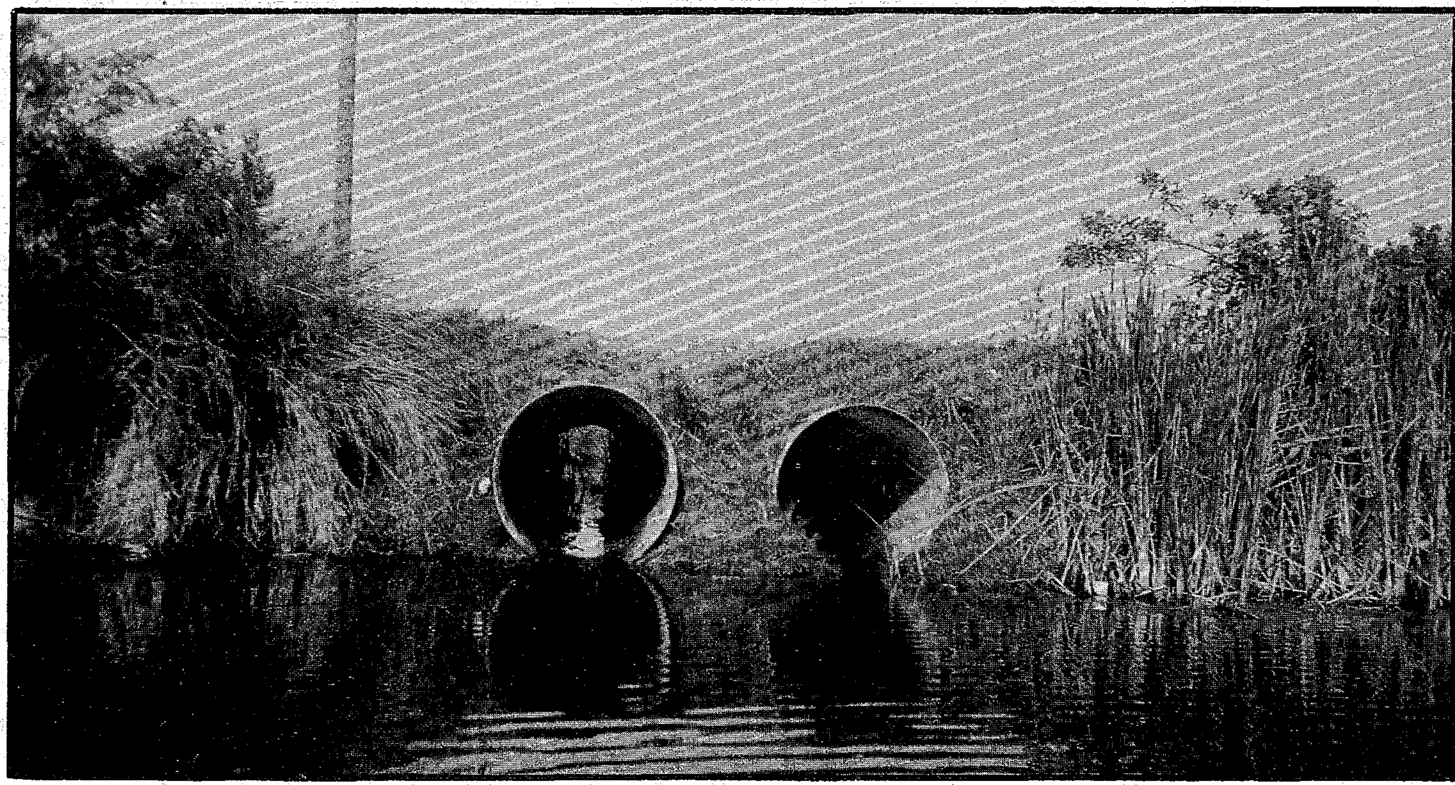


Figure 17.

Solid fill, which replaced the wooden bridges on Sanibel during the 1960's, has choked water flows and cut off many segments of the wetlands. The small culverts shown here do not provide adequate circulation.

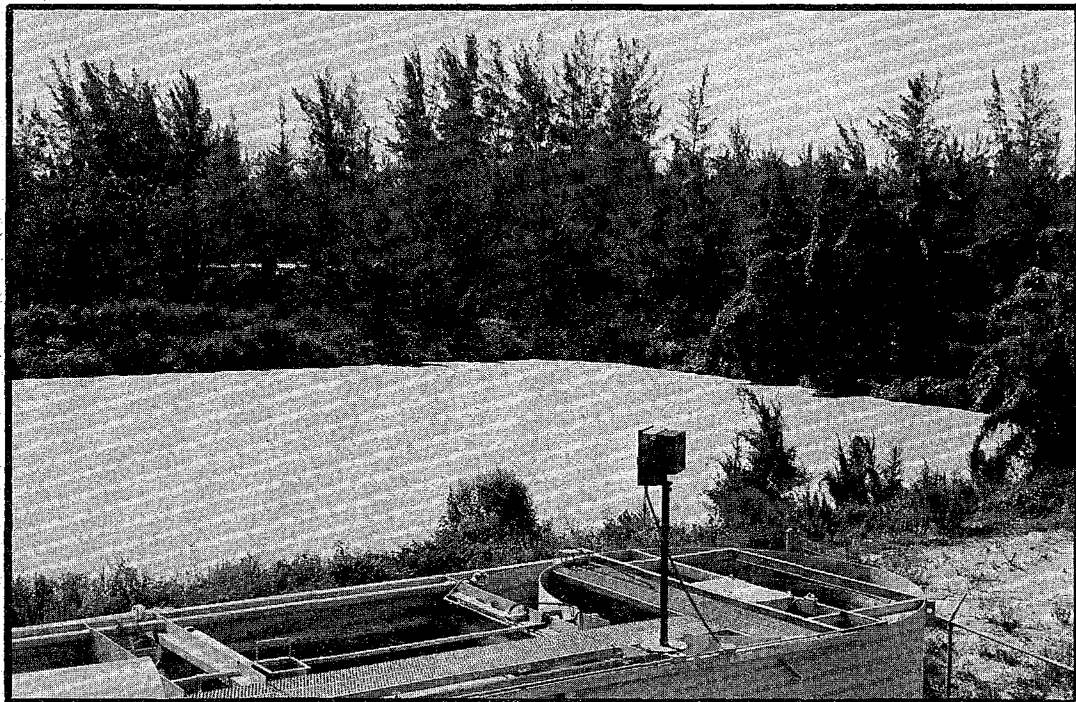


Figure 18.

High concentrations of nutrient in the sewage plant's treatment lagoon — indicated by the thick layer of algae at the surface — leads to pollution of adjacent waters by infiltration.

humans who drink the water or eat the shellfish.[21]

Sanibel's soils, as identified by the U.S. Soil Conservation Service, are Canaveral and Basinger types—marine deposits of sand and shell. These soils are characterized by rapid permeability (greater than 20 inches per hour) and a water table generally at depths of 10 to 40 inches below the surface for 2 to 6 months.[22]

These soil conditions impose moderate to severe limitations on many types of land uses, including the excavation of ponds, and the building of foundations and roadbeds. Also, Canaveral soil is not considered suitable for septic tank drainfields and sewage treatment lagoons because of its rapid permeability.

Central Sewage Treatment

The Jamestown Beachview Wastewater Treatment Plant, serving the eastern end of the island, is the largest treatment facility on Sanibel. During the winter, or "peak" season, this plant treats 0.5 MGD (million gallons per day) of effluent. In the off-season (summer months), treatment drops to about 0.225 MGD. The designed capacity of this plant is 1.2 MGD, with a total of 975 connections either existing or currently being installed. Secondary treatment is provided by two large aeration tanks in combination with two retention lagoons for bacterial breakdown of pollutants. (Figure 18) Effluent can apparently be disposed of on an adjacent, "abandoned" golf course (at Beachview Country Club Estates, which is currently undeveloped) using spray irrigation but it appears that most of it enters the groundwater directly. In the summer months, effluent amounts to 500,000-600,000 gallons a day. The possible presence of pathogenic organisms prevents spraying this effluent on lawns or the golf course of developed adjacent residential areas. However, effluent that is appropriately treated could be a valuable asset in view of the need for surface water replenishment in the fresh water management area.

The Jamestown Beachview plant is adjacent to the Sanibel River. Effluents from two retention lagoons enter directly into the groundwater and move quickly into the river, causing severe water quality problems. (Figure 19) The plant pumps up to 0.5 MGD into the lagoons and the water level has reached as high as 2-4 feet above that of the river. This hydrostatic head of water enhances the flow of pollutants into the river. Recent dissolved-oxygen data and unpublished tests by the Florida Department of Pollution Control indicate that the section of the Sanibel River adjacent to the plant may persistently violate both federal and state water-quality standards.[23] Dissolved-oxygen levels regularly fall below the 4 ppm (parts per million) standard. The owners of the plant have been directed by the Florida Department of Pollution Control to seal the bottom of the two lagoons to prevent migration of pollutants through the groundwater and surface-water systems. (Figure 20)

Package Plants

At present, the 20 package plants on Sanibel service approximately 300 dwelling units (principally hotels, motels, and condomimiums along Gulf Drive), and should, if properly operated, provide a higher level of treatment than septic tanks.[24] Several of them, however, cause or

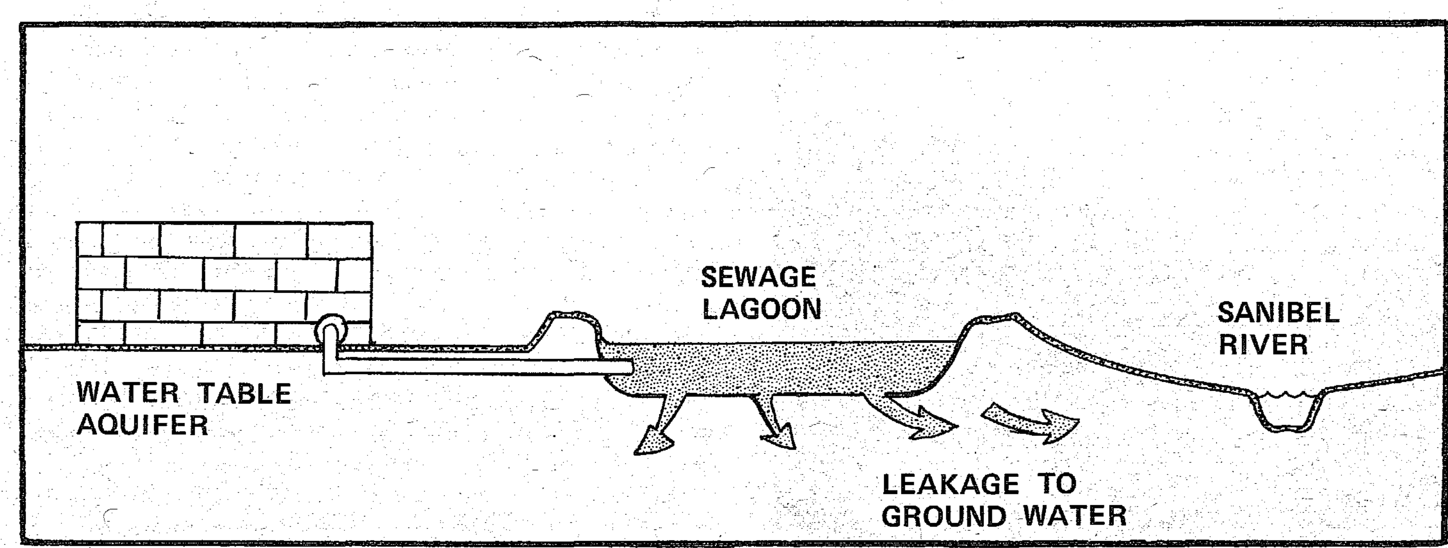


Figure 19.

Where pollutants from sewage lagoons have entered surface and groundwaters on Sanibel, serious water quality problems have occurred.

contribute to problems involving excessive nutrients in the receiving waters.[25] There has never been a coordinated plan for wastewater treatment on the island. Many plants are hapazardly designed, improperly located, and poorly operated. State regulations on treatment plant function are not sufficient to prevent serious degradation of Sanibel's water-table aquifer—quite simply, they are not designed for the difficult soil and water combination found on the island. (There is no law in the State of Florida setting minimum setback lines for package plants.) Worse still, several sewage plants are currently reported to be in violation of even the minimal state regulations. There is little water-quality data for the groundwater surrounding these plants—all of them, however, are located near small lakes, the Sanibel River, or mangroves and interior wetlands. Several plants have persistent breakdown and maintenance problems.

Septic Tanks

Approximately two-thirds of the households on Sanibel use septic tanks. Excess phosphate and nitrogen (which is particularly mobile in groundwater) is the probable cause of most over-fertilization and excess algal growth in Sanibel waters. As population density increases, far more serious groundwater pollution may become evident, because suitable physical conditions for minimal septic tank efficiency (particularly soil absorption) simply do not exist on Sanibel. Effluent that reaches the water-table aquifer, carrying bacteria and nutrients, saturates the soil and pollutes the groundwater. Soils on Sanibel are of such high transmissibility that the polluted groundwater can move rapidly through the soil and into surface water.

It is impossible to estimate how much of Sanibel's water pollution problems may result from septic tanks. Scientific research in coastal areas has shown that severe eutrophication of coastal waters—with resulting fish kills, noxious odors, and public health dangers—can result from septic tanks too close to surface waters.

In septic tank operation, wastewater from a home flows into a concrete tank where the solids settle to the bottom to be decomposed by bacteria into organic matter. Nutrients released during this process flow into drainage areas through subsurface tiles. Further percolation through the ground completes the treatment process. The nutrients often are taken up by trees and shrubs, or absorbed into soil particles. If the distance between a septic system and water is insufficient, the liquid waste leaching through the soil is inadequately treated and can pollute the water with a variety of substances. The most troublesome pollutants are nutrients, particularly nitrogen compounds. Nitrate (NO_3), which is particularly mobile in groundwater, is the probable

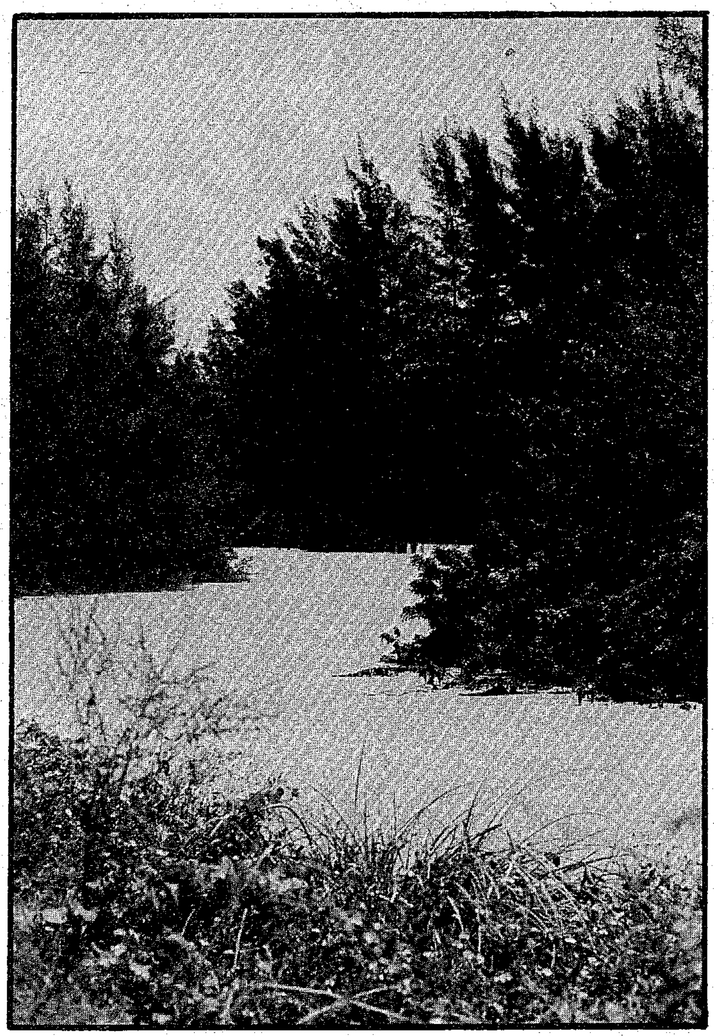


Figure 20.

Effluents from the sewage plant leak directly into the Sanibel River, polluting its waters and covering them with a thick algae layer similar to the one covering the sewage lagoon.

cause of most estuarine eutrophication.

State regulations typically require absorption fields of septic tanks to be set back a minimum distance from the edge of any stream, lake, open ditch, or other body of water into which unfiltered effluent could escape. The purpose of the setback is to allow for removal of pollutants—particularly coliform bacteria and other water-borne pathogenic organisms—from wastewater through soil purification before it reaches the adjacent body of water. Although these setbacks may be sufficient for removal of pathogenic bacteria—and there is growing doubt about this—they do not remove certain dissolved pollutants, particularly nitrates. Also, recent research indicates that viruses can travel long distances through groundwater—which further complicates the septic tank problem.

L. B. Leopold, a U.S. Geological Survey hydrology expert, has reached the following conclusions: 1) ". . . for soil cleansing to be effective, contaminated water must move through unsaturated soil at least 100 feet," and 2) "... no source of pollution such as seepage field [should be] closer than 300 feet to channel or watercourse."[26] Leopold added that even this setback does not prevent dissolved materials such as nitrates from enriching the water, thus potentially creating a biotic imbalance through eutrophication.

In a coastal area, a setback of 300 feet would be a safe starting point, unless local soil and groundwater conditions are particularly unsuited for nitrate removal—in which case an even greater distance should be considered. (Table 6) Setback standards that provide for nitrate removal are particularly important for Sanibel because nitrogen is the controlling nutrient for algal growth in the island's interior wetlands and mangrove areas.

Urban Runoff

Every acre of land on Sanibel is washed with 1.5 million gallons of rainfall each year. Pollutants washed from paved surfaces, roof tops, and fertilized lawn areas enter the soil and eventually can affect the water system.

Under natural conditions, rainfall drains through vegetation as overland flow or through the soils via groundwaters—thereby receiving highly effective purification and treatment. (Figure 21) In an urban area, the typical storm drainage system is designed to short circuit the natural system, and remove rainwaters as rapidly as possible. Runoff from an urban area frequently has characteristics similar to raw sewage. Contaminated runoff can be caused by yard refuse, septic tanks, garbage dumps, stagnant water, car washing, vehicle drippings, construction and maintenance operations, insect spraying (mosquito control), and fertilizers.[27]

The extent to which urban runoff contributes to Sanibel's water quality problem is not known—but is believed to be substantial. The problem will, of course, increase as population increases.

Calculation of Carrying Capacity Threshold

Consultant G. Kenneth Young performed an analysis of the relation of population and residential density to the natural assimilative capacity of the interior wetlands of Sanibel.[28] The purpose was to determine whether the wetlands had a pollution-loading threshold that if passed would seriously threaten any of the wetland's three major functions: 1) ability to assimilate wastes; 2) use as a wildlife habitat; and 3) potential as a secondary water supply.

The results of the holding capacity analysis are shown in Table 7. The curve represents the calculated holding capacity of the wetlands based upon a threshold of 4.0 ppm of oxygen; that is, to avoid violation of the federal minimum allowable oxygen standard of 4.0 ppm, it is necessary to remain below the curve. The curve suggests that there is a limit to waste loadings, that per-capita loadings increase at a rate even greater than population increase (because of increased non-point loading from increased land surface in use), and that the capacity of the wetland may have been exceeded already (as shown, in fact, by the degraded water quality of the Sanibel wetlands).

3. Water Level

Over the past 20 years, the natural drainage system of Sanibel Island has been channelized and expanded for a number of reasons. The former "course" of the Sanibel River was modified—deepened and widened. A network of canals and ditches was connected to it. An eastern subbasin was terminated by a series of deep tidal canals at Beach Road, where a structure to control water level was built. A western subbasin was extensively ditched, and the flow direction was reversed—discharge now occurs at Tarpon Bay through a control structure. (Figure 22) During high water conditions, water still may escape at the western part of the island. Roads cross the channel at several

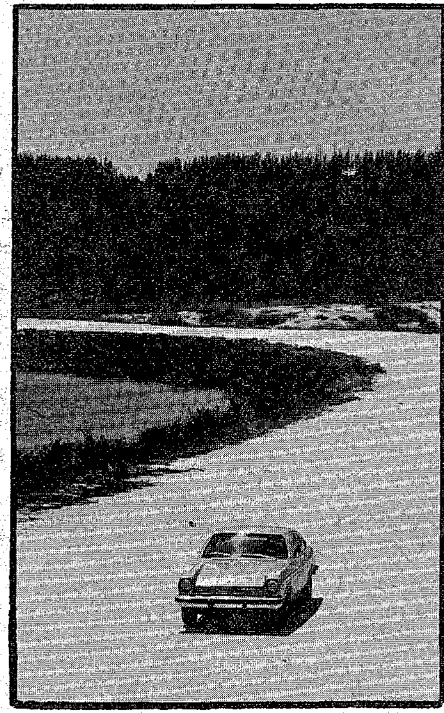


Figure 21.

Most of the rainwater that falls on this porous road will enter the soil and be cleansed; blacktop roads shunt the water directly to drains without purification.

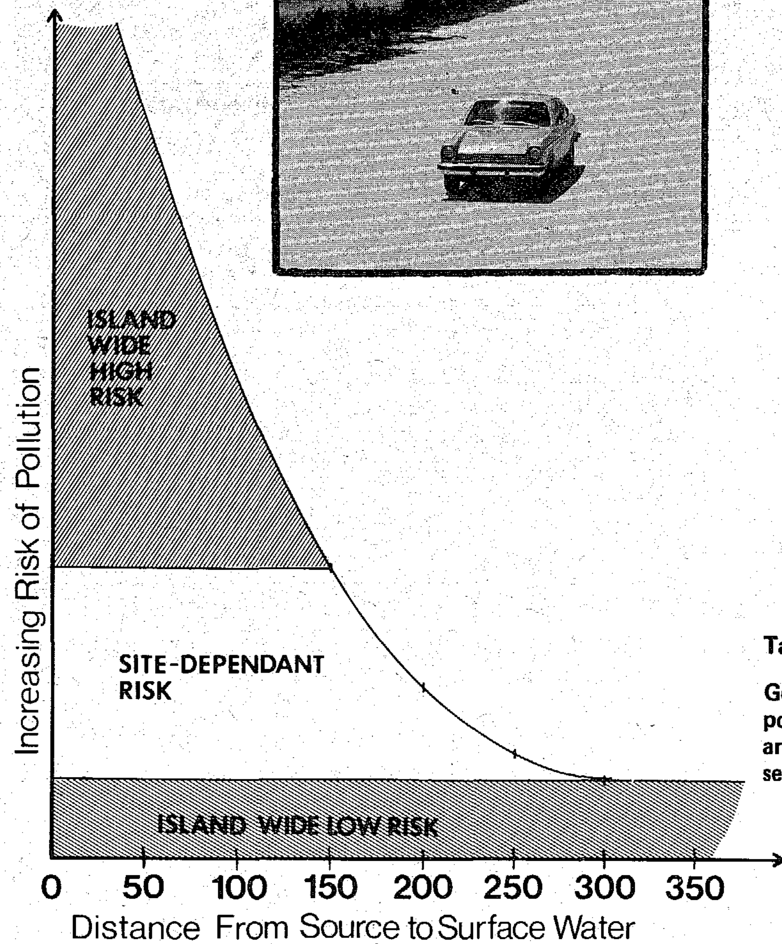


Table 6.

Generalized representation of pollution risk from nutrients and pathogens as related to septic tank setback distance.

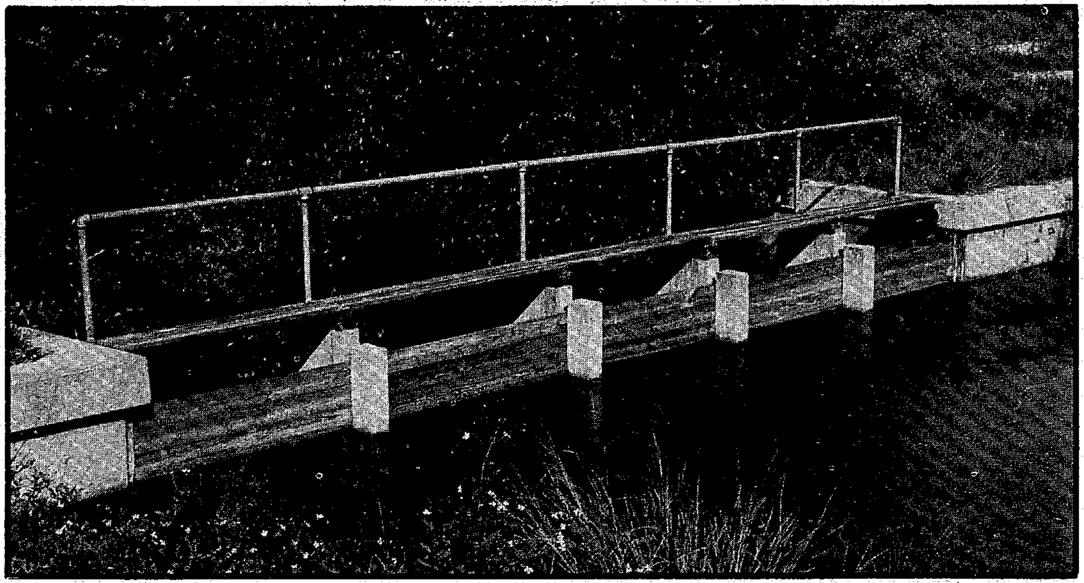


Figure 22.

Existing water control structure at Tarpon Bay will have to be improved to protect interior waters.

locations, with small culverts running beneath them. The culverts do not provide adequate connections, and during high water conditions interior flooding sometimes occurs.

Stage and Flow

Rainwater rarely discharges through the surface-water system of Sanibel Island. Sufficient rainfall must accumulate to raise the stage more than 2.5 feet above mean sea level before sustained discharge can occur at the control structures. According to U.S. Geological Survey stage data, this stage has been attained only twice since November 1970.[29] Minor discharges have occurred many times during the wet season because of leakage at both control structures, and because of tampering with the Beach Road control. (Figure 23)

Sanibel's present drainage system has had a pronounced effect on the water-table aquifer. Since the canals and ditches are dug through very permeable sand and shell,

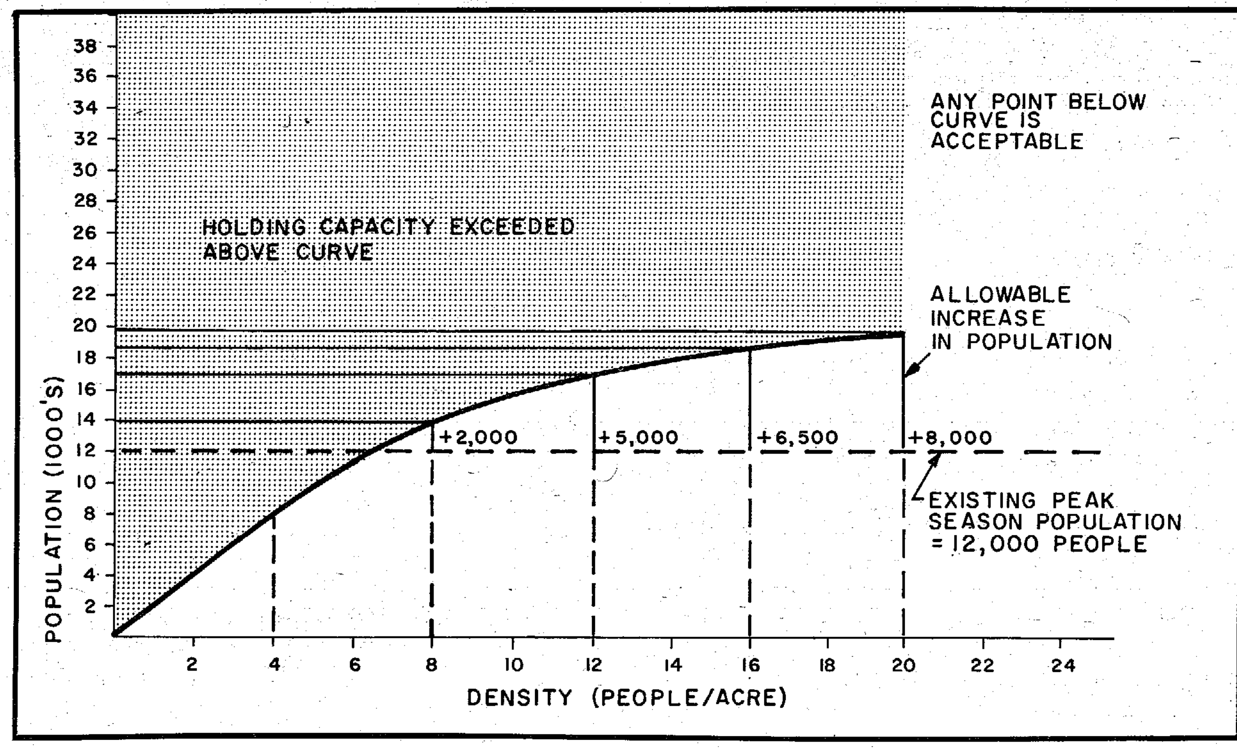


Table 7.

Maximum loading capacity of Sanibel's interior wetlands (for oxygen-demanding pollutants) shown by population and density.

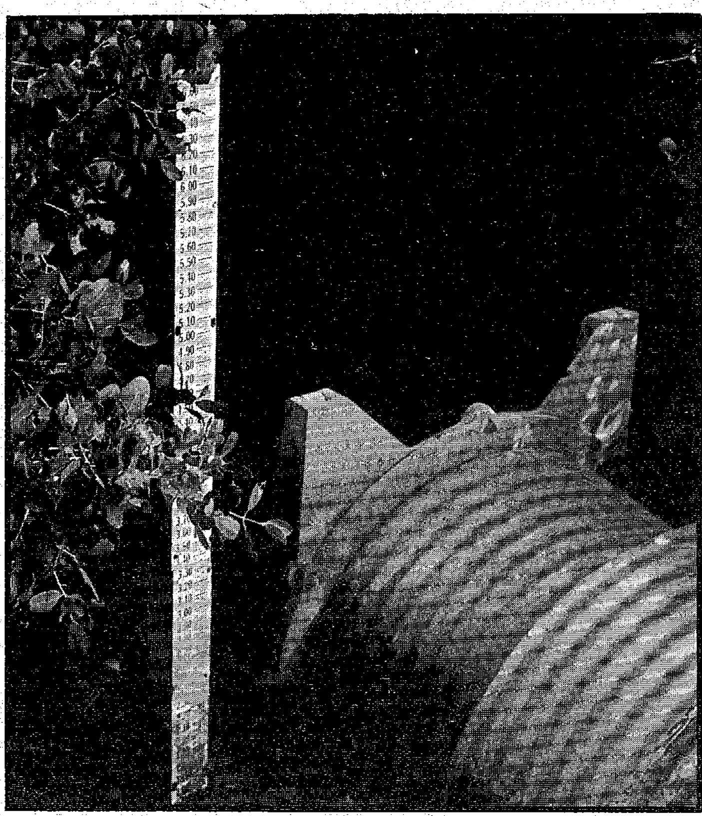


Figure 23.

This water control system at Beach Road was vandalized so often it finally had to be plugged with concrete in 1975.

water in the water-table aquifer flows rapidly out of the aquifer and into the adjacent canal where there is a positive gradient. This discharge from the groundwater system has increased the rate of recession during the dry season, and has caused temporary depletion of storage in the aquifer.

Salt Intrusion

Salt intrusion into Sanibel's ground and surface waters is a major problem—and it has worsened as development has increased. The problem is caused principally by lowering the water level in the interior basin. With the head pressure thus reduced, salt water can intrude into the freshwater areas in six basic ways: 1) intrusion of water directly from the sea into the water-table aquifer (Ghyben-Herzenberg intrusion); 2) leakage or intrusion of highly saline water into the interior surface and groundwater systems through uncontrolled or poorly controlled canals that are connected to tidal water bodies; 3) massive intrusion of highly saline water during tidal overtopping caused by intense storms; 4) upward leakage from the underlying shallow artesian aquifer; 5) discharge of highly saline water at the surface through improperly constructed, damaged, or uncontrolled artesian wells; and 6) pumping and dispersing highly saline water into the interior parts of the system.[30]

Saline intrusion has important ramifications for the island's ecosystems. Vegetation not adapted to salt water is destroyed by increases in salinity. Farming on Sanibel, for example, was ended by hurricane tides that covered the island in 1910, 1921, and 1926.[31] Many freshwater wildlife species cannot tolerate higher salinities. Finally, saline intrusion into the water-table aquifer causes problems for many residents who use this water for household needs.

4. Water Supply

In a barrier island environment such as Sanibel, sufficient supply of fresh water is a major problem. Under normal conditions, a shallow, unconfined aquifer, which contains fresh water, exists just below the land surface. Under conditions of limited urban settlement, when the demand for water is minimal, this source of fresh water could supply most of the demand, and can be replenished by natural rainfall. Excessive withdrawals from this freshwater reservoir upset the hydrological balance of the groundwater system. This system is extremely vulnerable to dramatic change primarily from three causes: saltwater intrusion (from flooding or groundwater), pollution from surface runoff, and effluent percolation.

Prior to 1973, Sanibel purchased water from the Pine Island Water Association, which tapped the comparatively shallow freshwater Upper Hawthorn aquifer. Escalated growth on Sanibel in the early 1970's caused increased demand and led to problems of water supply. Since the freshwater aquifer supplying Pine Island from the mainland was also limited, supply problems for Sanibel soon became apparent. The critical balance between water entering the ground and withdrawals from shallow wells was upset. When Sanibel installed its own water supply system (the Island Water Association [IWA]), the only water available to IWA of a treatable quality was found at depths between 500-600 feet.

In November 1973, IWA put its first brackish water treatment plant into service on Sanibel, utilizing the electrodialysis demineralizing or desalination process. The plant draws brackish water from wells 500-600 feet deep which tap the Lower Hawthorn aquifer. The Lower Hawthorn aquifer is a water resource which is recharged from a vast region, located many miles from Sanibel. As opposed to the shallow water-table aquifer on the island, no detailed study has yet determined the Hawthorn aquifer's supply capacity with respect to regional water demands. The USGS office in Fort Myers, with support from the city and IWA, is conducting a study of the Lower Hawthorn aquifer in order to determine Sanibel's needs versus regional supply and demand.

Construction of the existing system began in late 1972 and went into service in November 1973 (with the first of four phases of the treatment plant in service, it produced 1,200,000 gallons per day). This plant, which has since been expanded to a capacity of 1,300,000 gallons, is currently the primary source of water for both Sanibel and Captiva. The fixed interconnection between the two original systems (from Pine Island) is still in place and ready for service. On an emergency basis, water can be transmitted from Pine Island to Sanibel, and from Sanibel to Pine Island. Suitable metering devices are becoming available. The water plant on Sanibel draws brackish water from deep wells located near the plant site. The water is treated by aeration and filtration, and then chlorinated for distribution in a reservoir on the site. All of the required mechanical, chemical, and distribution equipment is in operation.[32]

The IWA distributes the treated water from its main plant near Rabbit Road to two remote pumping stations—the Sanibel Booster Station (near the intersection of Periwinkle Way and Dixie Beach Boulevard) and the Captiva Substation (located approximately one mile from the south end of Captiva Island on State Road 867). These two pumping facilities distribute water to the east end of Sanibel and to the north end of Captiva, respectively.

5. Recommendations

Water Quality

There are four principal threats to water quality on Sanibel: 1) discharge of polluted effluents; 2) storm water runoff; 3) pollutants conveyed through groundwater; and 4) salt intrusion of ground and surface waters.

The Conservation Foundation recognized the urgent need for a central sewage system, but was concerned that the island might not be able to assimilate the effluent discharge into the ground. Certainly the area of the interior wetlands and river adjacent to the present disposal site for the Beachview plant is grossly polluted. Higher levels of treatment may help, and better receiving areas may be found. Nevertheless, the ocean disposal option should not be dismissed at this time. Federal requirements appear to permit ocean disposal of secondary effluent under certain conditions.

The combined effects on Sanibel's surface waters of runoff pollution and leaching of sewage have been estimated by G. K. Young. Young has calculated that, with the best expected levels of treatment of sewage effluent, the combined effect would overwhelm the assimilative capacity of the wetlands—leading to unacceptable water quality when the total island population approached 20,000[33] Thus, there is a definite water quality limit to the occupancy of Sanibel.

Discharge of Polluted Effluents (point-source)

Direct discharge of wastes as concentrated point-sources is not now a major problem on Sanibel and should not become so in the future. It appears that neither sewage effluent nor industrial wastes are discharged *directly* into Sanibel waters at the present. Since water quality on Sanibel is so easily degraded, however, the city should take precautions to ensure against any such discharge in the future.

Storm Water Runoff (non-point)

Contaminants that are washed off land surfaces into surface waters by rainstorms (diffuse sources, or non-point pollution) are now responsible for some water quality degradation and are likely to become a severe problem in Sanibel's future unless a definite control program is initiated. The Conservation Foundation made the following recommendations to the Planning Commission and WMRT:

1) On-site retention of storm water should be standard practice for all residential and commercial developments, thus eliminating any diversion of storm waters to the interior and wetlands water system, or to the gulf or the bay. This can be accomplished by installing detention ponds and infiltration enhancement devices such as "French drains." Rainfall should be retained on the island to the maximum extent possible because it is Sanibel's only natural source of fresh water.

2) Impervious surfacing should be kept to a minimum, and unsurfaced roads should be used to the maximum extent possible. Special standards are required for Sanibel because of the high pollution vulnerability of its waters. For example, blacktop parking lots and hard-surfaced roads and driveways should be discouraged. Sand and shell roads and driveways should be encouraged, along with a wide variety of permeable surfaces available for parking lots or patios.

3) To provide sufficient filtration and purification of runoff water from developed parts of the island it is necessary to require a buffer strip of natural soil and vegetation around all open water areas. This will permit infiltration and vegetative scrubbing (removal of contaminants) of runoff before it reaches open water areas. The buffer is particularly important where there are definite sources of pollution, such as lawns or golf courses, that would be heavily fertilized or treated with pesticides. A setback of 150 feet would be effective and should provide sufficient filtration potential where chemical applications are moderately heavy. The buffer might be required routinely but its width decided on a case-by-case basis, with project sponsors required to show that a lesser distance would meet the water quality standards.

Pollution Conveyed through Groundwater

The most threatening water pollution problem of Sanibel may be the leaching of sewage pollution through the shallow groundwater and into the open surface waters. The sources are septic tanks, package plants, and the Jamestown-Beachview treatment plant. The Conservation Foundation recommended the following:

1) The appropriate long-term solution is replacement of all existing facilities (septic tanks, package plants, etc.) with a modern island-wide secondary sewage treatment system with off-island disposal of effluent, or an advanced system with the effluent used to recharge the groundwater.

2) Short-term solutions would involve upgrading the operation of the Jamestown-Beachview sewer plant and all deficient package plants, and applying strict standards to location of leaching fields for any new septic tanks or package plants. Leaching fields should be set back a sufficient distance so that contaminants do not reach surface waters. This may require a setback of several hundred feet from the edge of adjacent surface waters for package plants.

Individual septic tanks set back less than 150 feet invariably contaminate surface waters with excess nutrients. Sanibel, because of saturated, highly permeable soils with low organic content, obviously must have higher standards than other coastal areas. Therefore, a setback greater than 150 feet is needed. The following specific suggestions for septic tanks were offered:

2.1) In most cases, a 300-foot maximum setback should provide for removal of excess nutrients before entering surface waters.

2.2) A lesser setback in the range of 200-250 feet might permit the minimal required removal of nutrients and pathogens under certain situations; research specific to each site will be needed to confirm this recommendation.

2.3) Immediate research should be conducted in the 200-250 foot range to establish island-wide standards for present use; it will be necessary to retain the minimal 200-foot setback.

2.4) Later, a detailed research program to explore the 250-300 foot and 150-200 foot ranges could be mounted with a view to developing multiple standards that are sensitive to the hydrologic differences between ridges, interior wetlands, and shore sites.

2.5) In addition to setback requirements, it is recommended that the drainage pipes of the absorption field be placed at least four feet above the highest expected annual groundwater level. On Sanibel, where the groundwater beneath the septic tank absorption field can rise to the level of the discharge pipes, the saturated soils cannot absorb the effluent. In the worst situations, the unpurified effluent may even rise to the surface where it will drain directly into an adjacent body of water.

3) All sewage-treatment ponds should be sealed to prevent sewage infiltration of the water-table aquifer and pollution of surface waters.

4) The goal is that water leaching through the ground shall not degrade surface waters; specifically, it should not contain higher concentrations of contaminants at its point of entry than the maximum permitted for surface water (by water quality standards). A principal difficulty, and one that requires the broad setback, is the control of nitrogen. Unlike phosphorous, nitrogen is quite mobile in groundwater. Nitrogen control is necessary to prevent overfertilization or eutrophication of the water, which leads to algae blooms and oxygen reduction.

Salt Intrusion of Ground and Surface Waters

Indirect pollution of the surface waters and water-table aquifer of Sanibel by saline ocean water is a serious problem. Because of salt intrusion the water is rendered unfit even for watering lawns in many parts of the island over many months of the year. Salt water enters surface and groundwaters in four ways: 1) by infiltration through both gulf and bay sand-shell ridges that enclose the interior wetlands basin; 2) by passing through and around the control structures at Tarpon Bay and Beach Road; 3) by storm surge inundation of the island during heavy storms and hurricanes; and 4) by upward leakage of saline water through the clay seal that underlies the shallow surface aquifer. Once in the island water system, the salt tends to sink and remain (salt water being heavier than fresh); salt

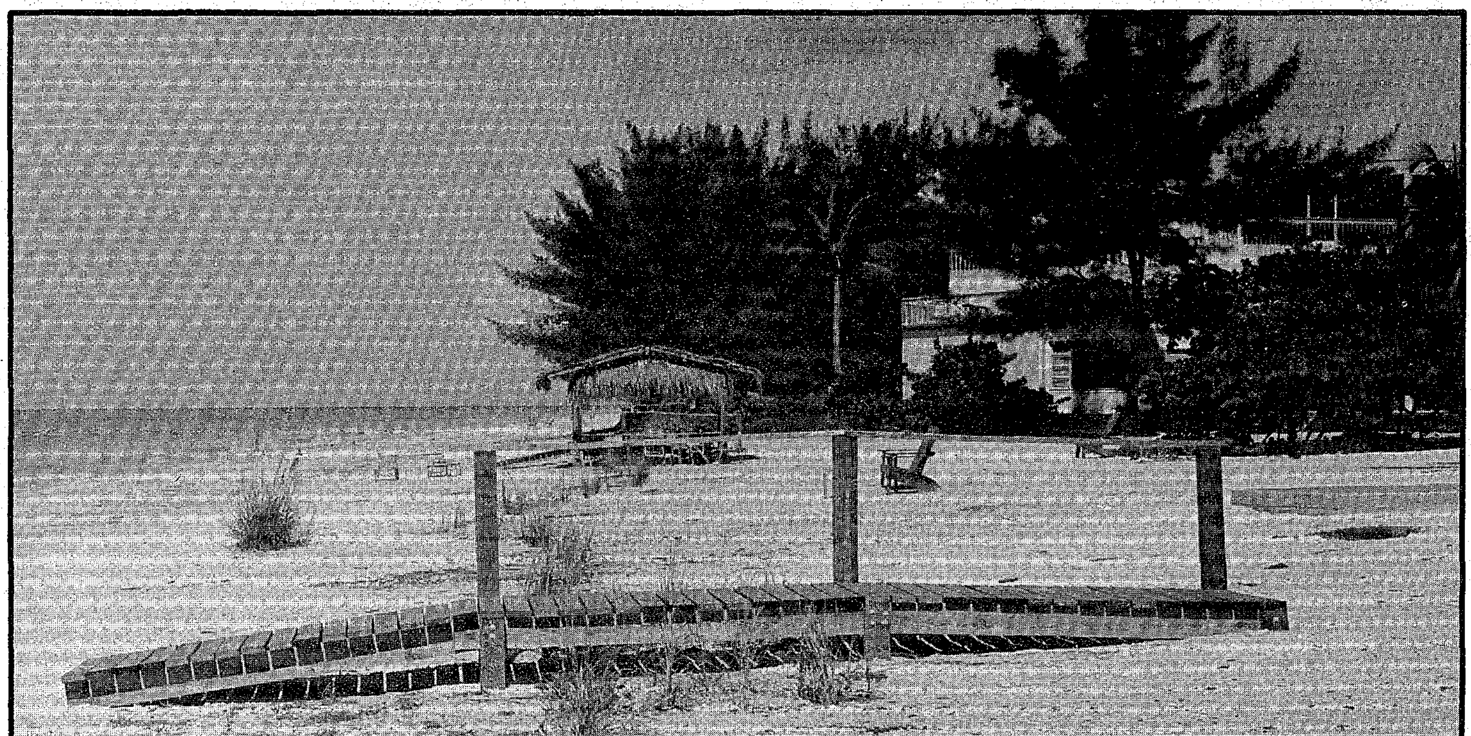


Figure 24.

One of the first dune replantings since plan adoption; the beach grass should prosper and in time develop a natural beach ridge (low dune).

becomes more concentrated in surface water bodies because of evaporation.

Each cause of salt intrusion has a different remedy. The Conservation Foundation recommended the following:

1) Infiltration through the gulf and bay ridges can best be remedied by maintaining a positive head of water in the interior basin. That is, the city should make the strongest possible efforts to maintain the level of water in the basin above the high tide level of the surrounding sea for as much of the year as possible. The water management level restoration program outlined on page 39 would provide this remedy.

2) Passage of salt water around and through the control structures can be remedied by improvement of the control structures through state-of-the-art engineering.

3) Storm surge damage can be remedied or mitigated by restoring and protecting the beachfront and ridgeline (Figure 24); prohibiting the digging of man-made lakes for borrow pits and refilling as many existing lakes as possible; preventing construction of any waterways directly connecting the island to marine waters; and refilling as many existing canals as possible. (Figure 25)

4) Upward leakage of saline water through the clay seal can be remedied by keeping a positive head in the interior basin and by preventing any puncturing of the seal by excavation, structural penetration, or drilling of wells. Existing open test well holes should be plugged. These remedies are discussed further in the chapter on uplands.

Pest Control

The major pest of Sanibel is the salt marsh mosquito, although there are some problems with biting flies. Ecologically damaging pesticides may reach Sanibel's surface water systems by runoff, groundwater flow, or direct aerial application to the water surface. In an ecosystem such as Sanibel's, great care must be taken to avoid chemical pollution. The Conservation Foundation recommended the following:

1) While the authority for pest control operations clearly lies with the Lee County Mosquito Control District, the city should discourage the Lee County Mosquito Control Commission from the use of chemicals for controlling mosquitoes on the island, except for the emergency use of short-lived, benign chemicals. (Figure 26)

2) The city should incorporate into its water management program an element for maintaining the best possible level of mosquito control through an effective water management program.

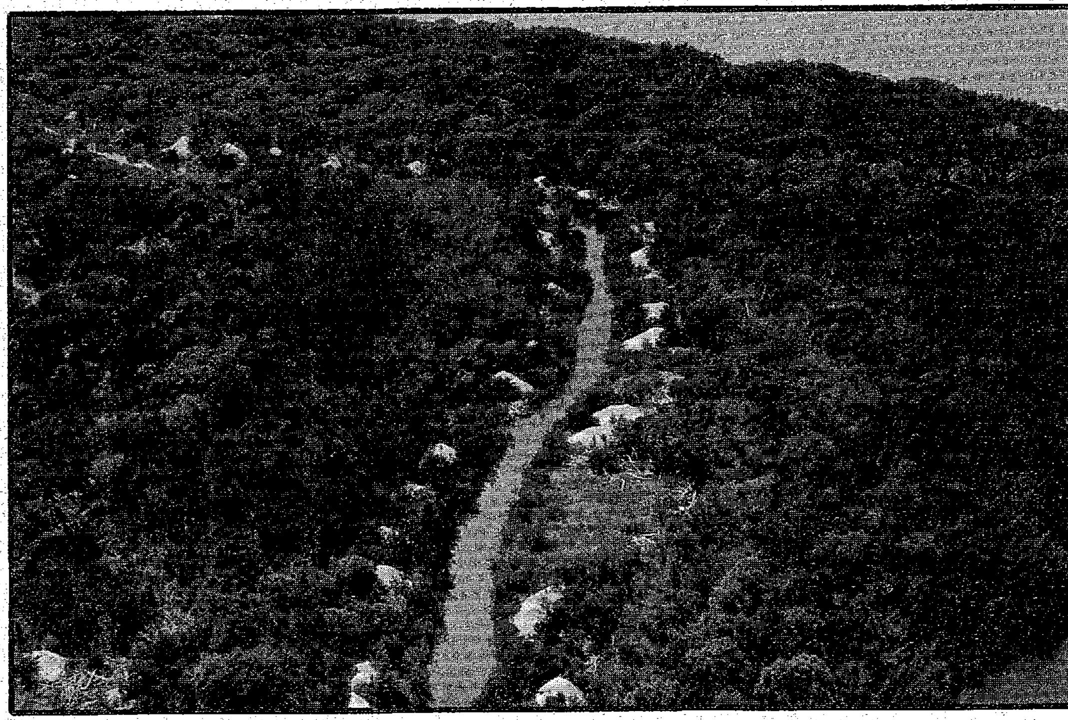


Figure 25.

An example of the type of canal that depletes groundwater and allows saltwater penetration.

Relevant State and Federal Requirements

Sanibel's water quality protection efforts should supplement the programs of federal and state agencies. The extensive water quality program, under the Federal Water Pollution Control Act of 1972, P.L. 92–500, is operated in Florida through the state's Department of Environmental Regulation (DER). Among its various elements, this program requires the elimination of polluted discharges, the maintenance of high standards of water quality, and control of polluted storm runoff water.

The Federal Water Act requires that all discharges of pollutants to water be eliminated, and establishes a schedule for cleanup to be accomplished by 1983. Accordingly, all such discharges to the water of Sanibel Island should be terminated. This includes all point-source discharges to surface waters of the island, including the Sanibel River (and its tributaries), ponds, man-made lakes, and all wetlands. Point-source pollution includes all polluted effluents collected and conveyed by pipes, channels, ditches, or conduits of any kind. (Each such point-source requires a permit from the DER certifying that the discharge creates no significant pollution problem.)

Sanibel cannot, however, simply rely on federal and state governments to protect and restore its water quality. There are now widespread violations of federal and state pollution regulations on Sanibel, notably in instances where sewage has leached through groundwater and into open surface waters.

In addition, the natural systems of Sanibel require special protection that is not provided by present regulations. For example, the present minimum requirements for septic tanks set by the state (a setback of 50 feet from open water, 75 feet from wells, and 36 inches above seasonal high-water level) are totally inadequate for Sanibel.

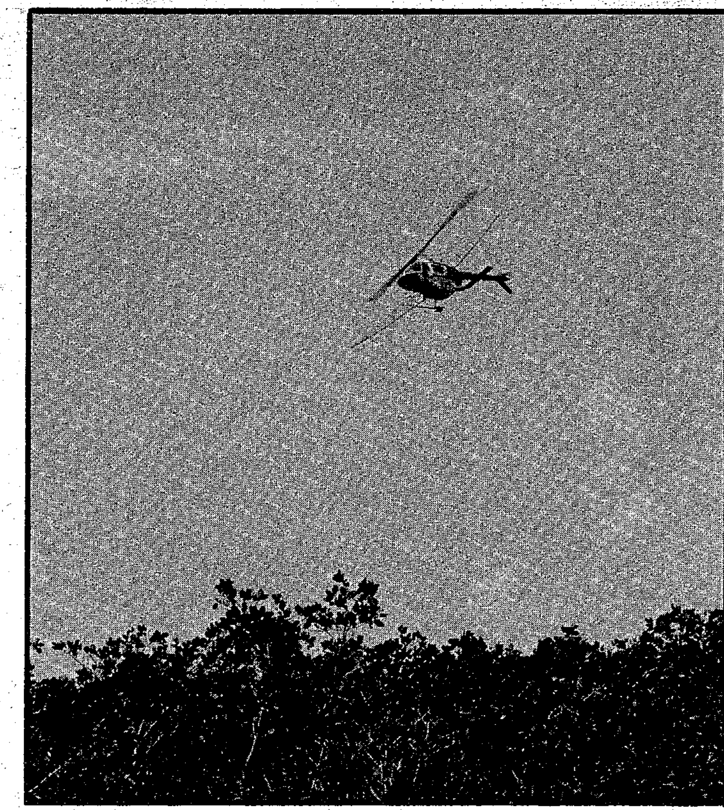


Figure 26.

Little is known of the true ecologic effects of the new generation of chemical poisons such as fenthion used on Sanibel to control insects, but EPA research in 1976 has led to increased concern.

Water Conservation and Water Level Restoration

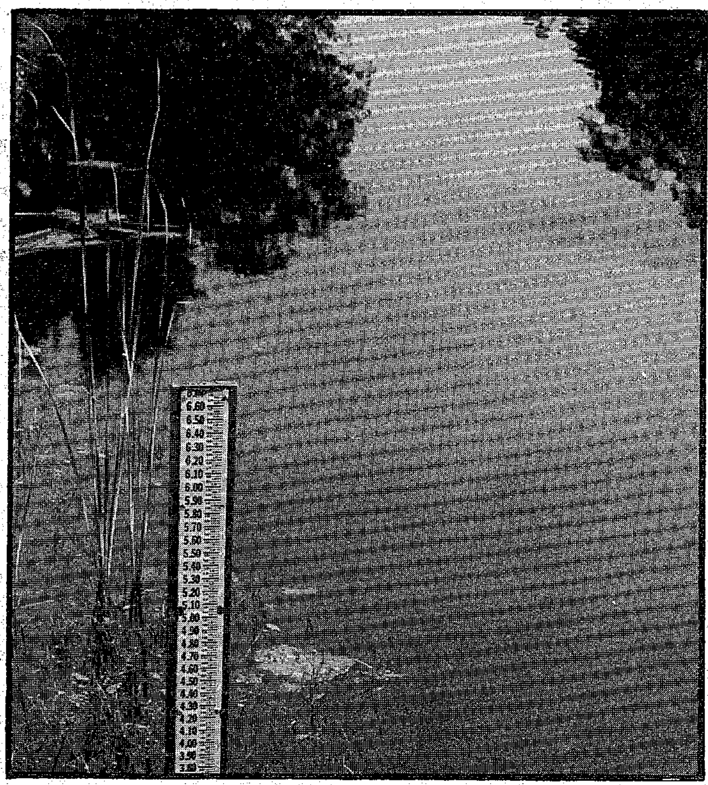
The development of Sanibel has significantly lowered water levels throughout the island. Restoration of natural levels (or as near to those levels as can be achieved) is essential to push back and displace the invasion of salt water, to provide improved water quality, to conserve fresh water, to perpetuate wetlands, to control mosquitoes, and to benefit vegetation and wildlife.

The water-table aquifer of the interior basin serves as a major potential secondary water supply for home use. This basin should be treated as a reservoir and protected as such. Soil and vegetative elements should be preserved, water quality should be protected, and storage capacity and replenishment should be maximized. If its condition is maintained, it can supply utility water for the home and yard from widely spaced individual wells.

Studies confirm that the major values of the interior basin are enhanced by the *highest possible* water levels. Accordingly, a policy of water-level restoration was recommended to the city. (Table 8)

In this connection, it is important to note that improving the flood conveyance capability of the Sanibel River and other parts of the system will cause the average water-table level to *decrease.* As it now stands, with a fixed height of 2.5 feet at the Tarpon Bay control structure, the water several miles away along the river may stand at 3 or 4 feet. If the channelways are cleared, the water level will drop at these more distant points and the total storage capacity of the basin will be reduced. Therefore, the Tarpon Bay control structure must be elevated above 2.5 feet if the channelways are cleared in order to maintain the *present* storage capacity of the system.

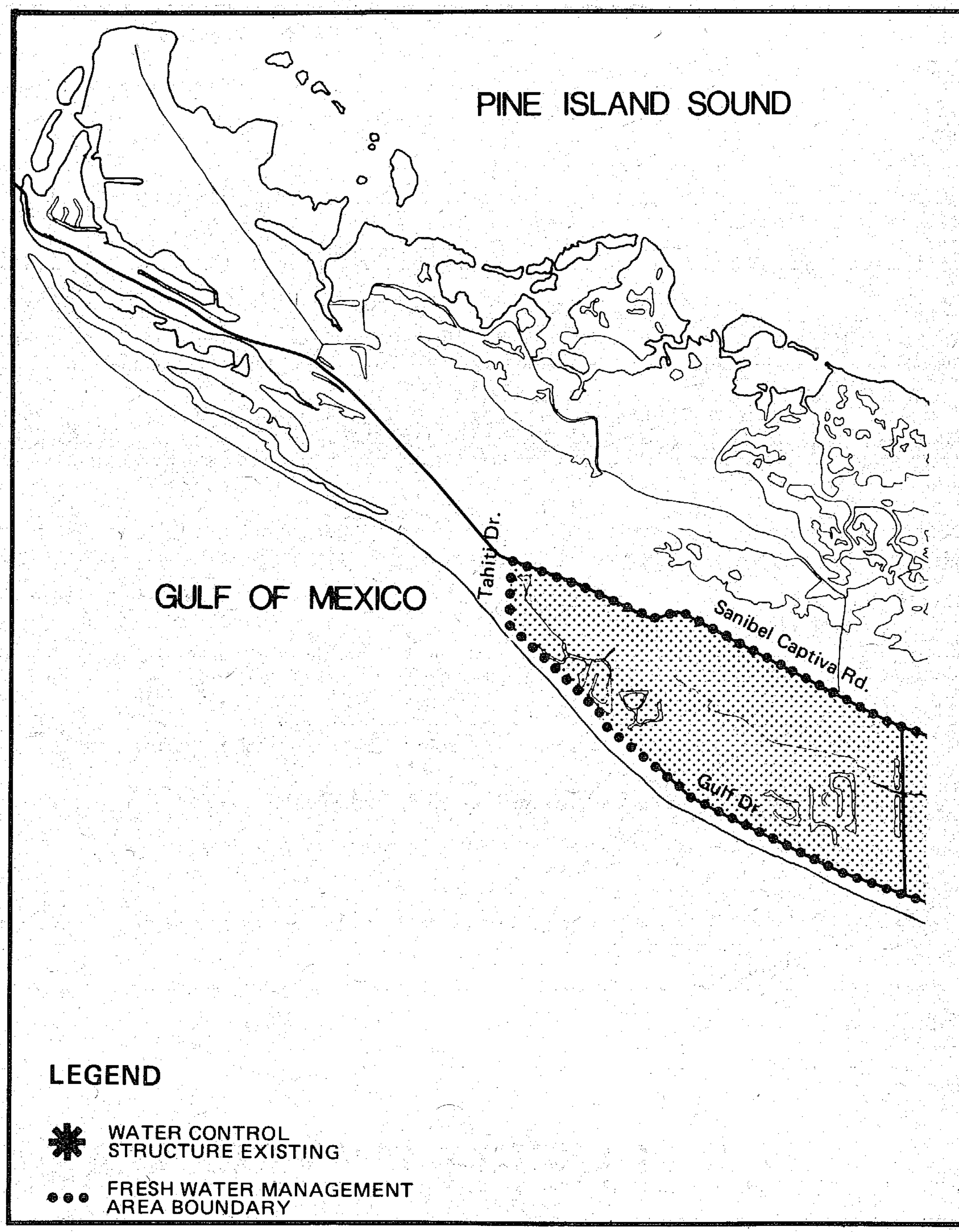
Although restoration would benefit all parts of the island, it would particularly benefit the interior wetland basin. Water there should be elevated to the highest practicable level in the rainy season. It should then be maintained at the highest practicable level through the dry



season. This requirement was identified independently by most of The Conservation Foundation's consultants, and in separate, earlier studies by Johnson Engineering, Inc.,[34] Provost,[35] and Boggess.[36] Different water management tactics may be required for each of the four major segments of the interior wetlands basin. (Figure 27)

The Conservation Foundation recommended the following:

1) The water level should be about four feet above mean sea level at seasonal maximum in each segment. Such a level may be difficult to achieve, however, because of natural soil porosity in most of the segments, and other factors such as leaks in the natural sealing layers of clay. It appears advisable to install a fixed sill up to 3 feet above mean sea level with options to 3.5 feet and 4 feet. Sills should be designed to permit drainage of the system for occasional remedial flushing, as recommended in the Johnson Engineering study.[37]



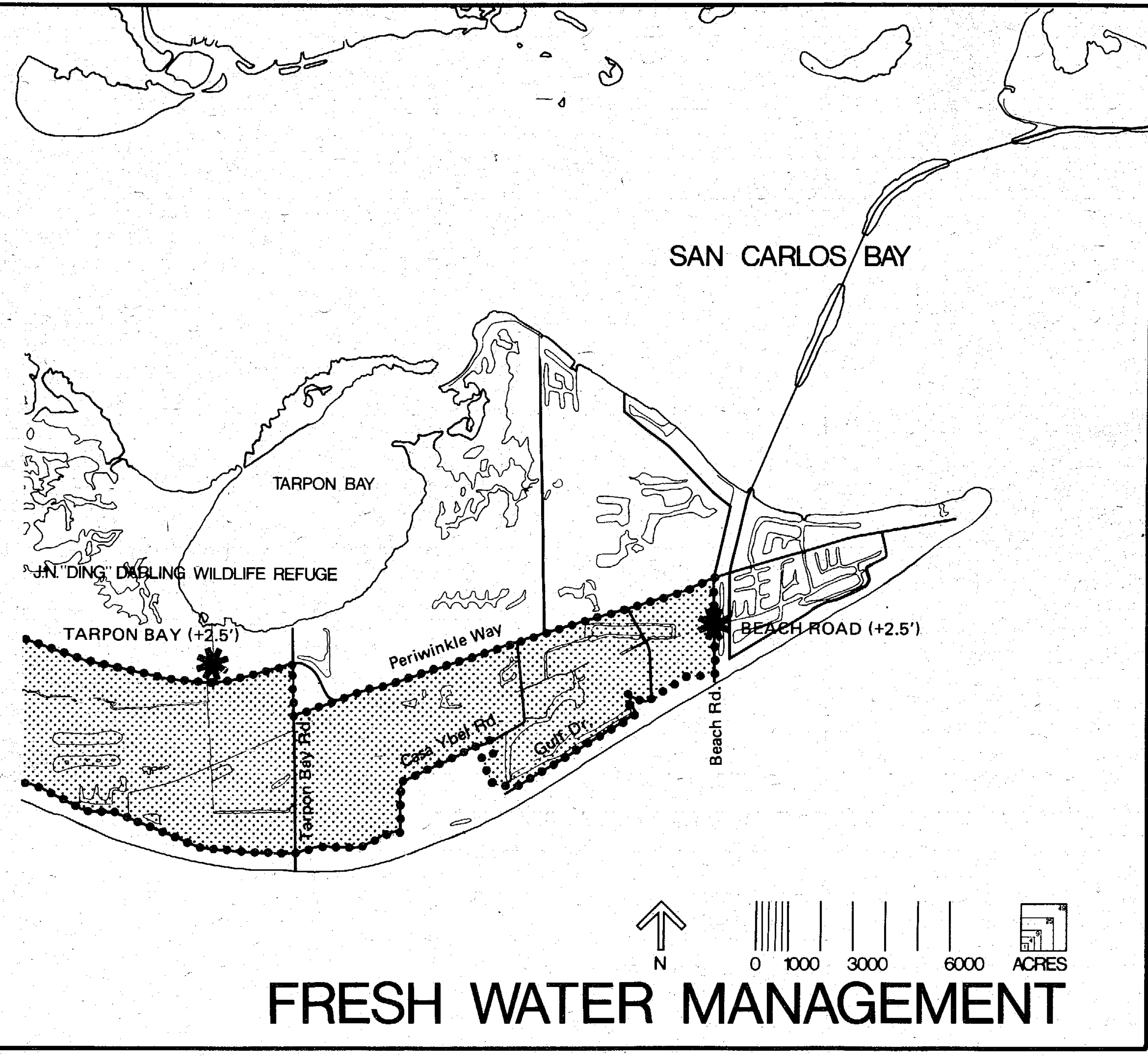


Figure 28.

Water levels in Sanibel's interior are recorded to determine ecological relationships involving water level.

Figure 27.

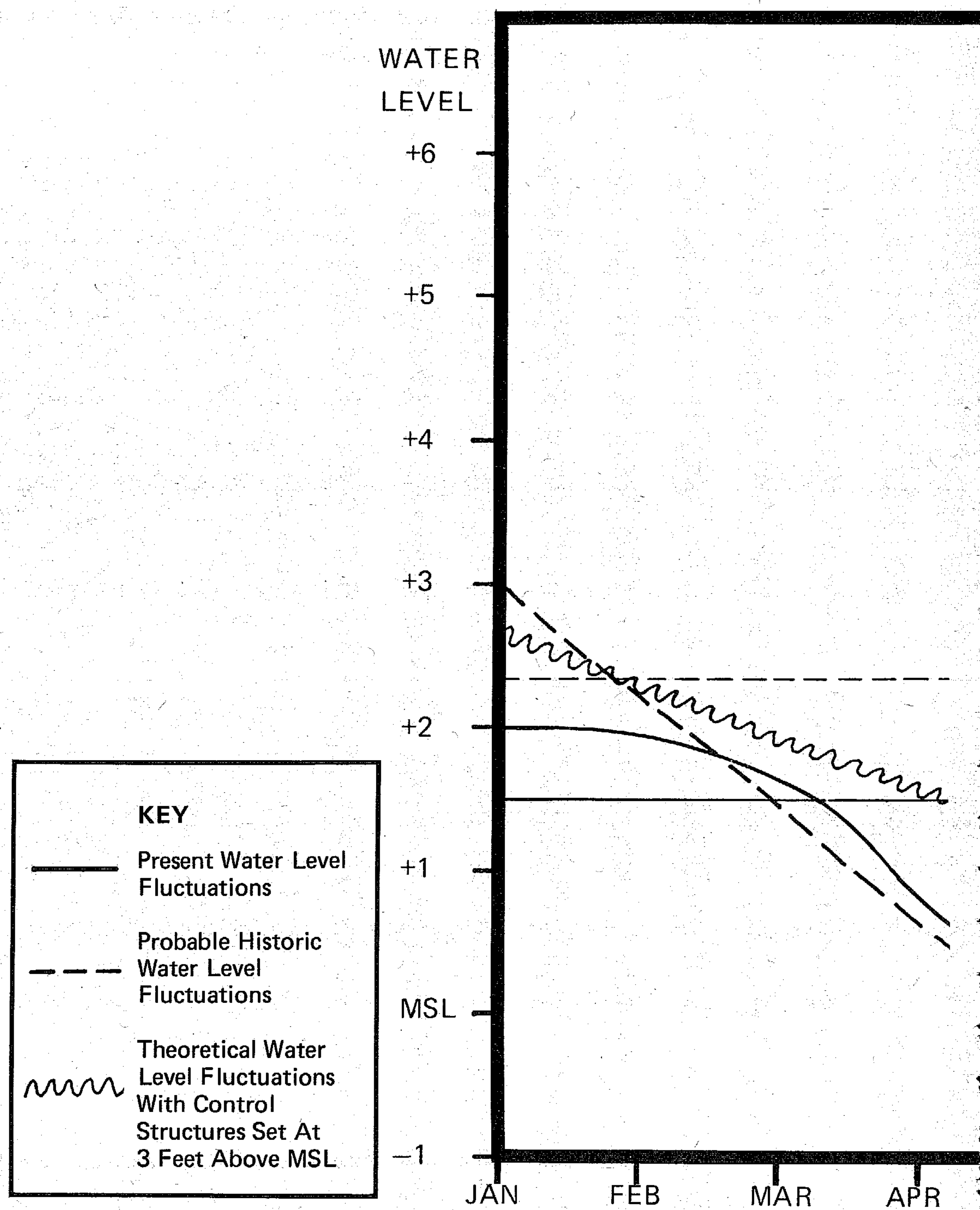
Sanibel's interior wetlands basin is a giant water reservoir and regulator controlled by structures at Tarpon Bay and Beach Road; strategic segmental control is recommended for future management. (Source: Johnson Engineering, Preliminary Plan, Sanibel Island Fresh Water Management Area).

2) The city should attempt to plug any major leaks that permit the loss of fresh water from the interior basin. The Tarpon Bay and Beach Road outlets should be improved to prevent the bypass of water around them and leakage of water through them. Other significant water outflows around the rim of the basin should also be identified and remedied. Excavations or structural penetrations of the clay layer separating the water-table aquifer and shallow artesian aquifer should be prohibited.

3) Water-level restoration may cause excess water to accumulate at the eastern and western ends of the interior wetlands system. If a practicable means can be found, excess water in the western part of the wetlands might be discharged to the J. N. "Ding" Darling Refuge. Excess water from the east end of the wetlands basin might be discharged into the artificial saltwater canals for the purpose of flushing them and improving their water quality.

4) Restoration of natural levels in the interior basin will increase reliance on the Sanibel River and tributary drainages to remove storm waters rapidly and thereby avoid flooding; some channel improvements should be undertaken for this purpose.

5) Outside the interior basin, the city should also try to restore natural water levels. This restoration would require that drainage be prohibited and that existing adverse drainage conduits be filled up or otherwise blocked.



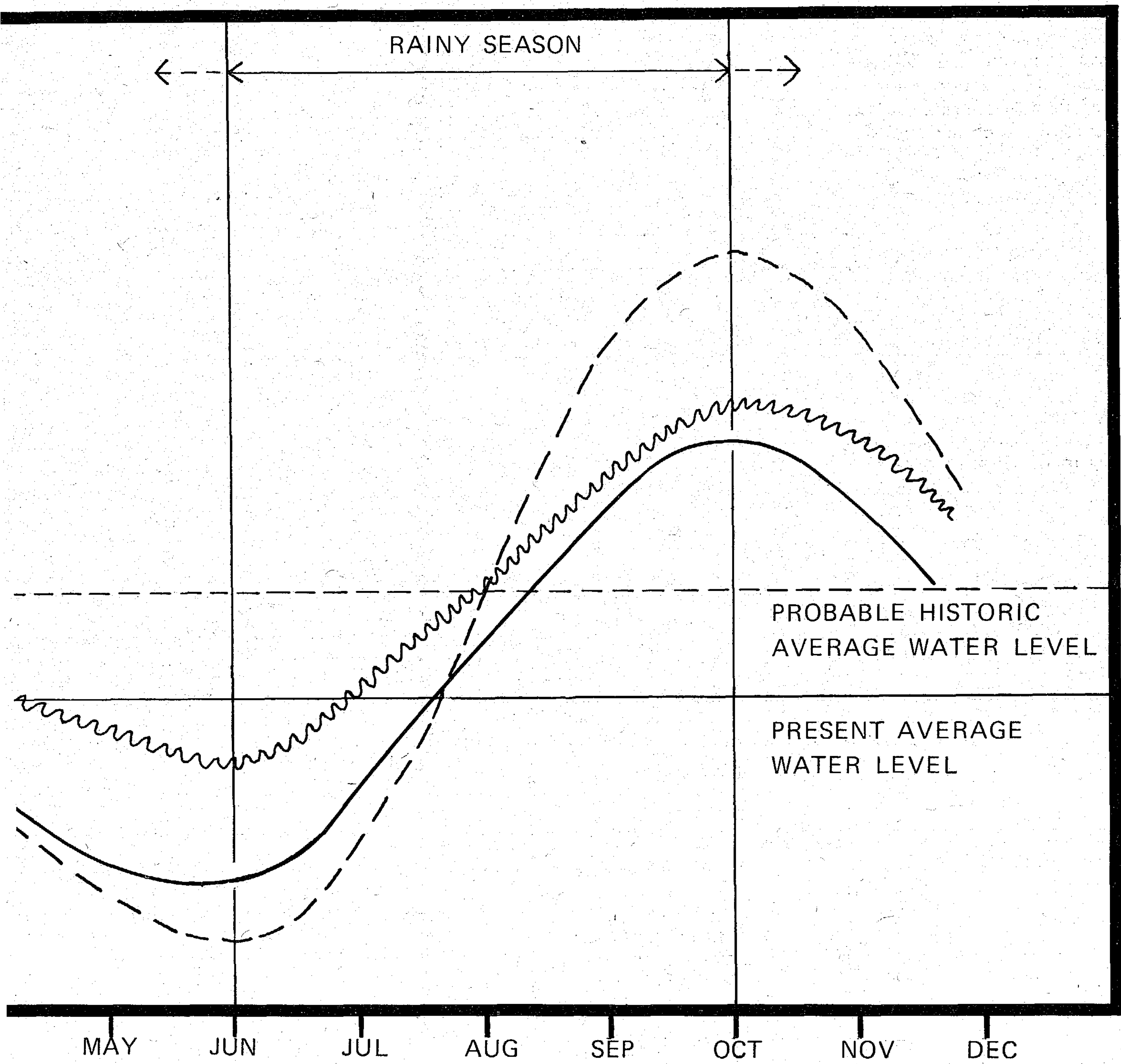


Table 8.

Water control structures, channelization, and other modifications to the water systems alter groundwater levels and runoff rates. Water systems can be restored, however, with appropriate engineering. (Drawing prepared by Langdon Warner).

CHAPTER 3

BEACHFRONT

Identification of Gulf and Bay Beaches

The Gulf Beach Zone includes the area between the state setback line, approximately 150 feet inland from mean high water, and the city boundary 300 feet offshore. There are two subareas within this zone: the Front Beach and the Back Beach. The Front Beach extends from the city boundary to mean high water mark. Sand in this subarea is in constant motion, migrating between the berm and offshore bars, transported by longshore currents. The Back Beach comprises the area between mean high water and the state setback line. Sand in this subarea is moved by wind and water, and stabilized by vegetation.

The Bay Beach Zone extends from the city's boundary 300 feet into the bay to a setback line of about 50 to 100 feet behind the mean high water mark. It is a lower-energy beach than the Gulf Beach, and includes areas of marine grasses on the bay bottom.

Surface Hydrology: The seawater in the beach zone rapidly percolates through the sand and shells into the water-table aquifer and into the shallow artesian aquifer. A 10-year storm flood inundates the entire beach and all other zones of the island except the Gulf and Mid-island Ridges. A 25-year flood inundates the entire island.

Soils: Because of extremely mobile conditions of the sediments, the beaches have not developed soil strata. The ocean beaches consist of oxidized barrier sands and shells. The bay beaches are made up of mud, organic materials, sands, and shells.

Sanibel's gulf (oceanside) beaches are backed by a temporary berm at the high tide mark and a relatively permanent line of dunes. Mild summer waves add sand to the berm, and prevailing onshore winds move sand from the berm to the dunes. During heavy storms and hurricanes, the berm may be completely reclaimed by the ocean, at which time the dunes must erode to replenish the lost sand. The berm moderates these changes by providing a reservoir of sand available to either dunes or beach as needed.

A sandy beach exists on the bay shore near the eastern end only. The rest of the bay is mud and silt.

Vegetation of the Beachfront: Sanibel's beaches support the beach plum-railroad vine-sea oats association.

Grasses, herbs, and shrubs on the beach are often inconspicuous and widely scattered. They have extensive root systems and offer limited shade to insects, crabs, and small reptiles. They usually produce an abundance of seeds which serve as food for many wildlife species. Some

Figure 29.

The Australian pine has invaded much of Sanibel, including the beachfront.

velop fruits which are eaten by birds, mammals, and humans. All of these plants are salt tolerant, and their extensive root systems stabilize dunes. They are an integral part of the island's buffer system against storm waves and high tides.

The beach plum-railroad vine-sea oats association of species has been especially successful at adapting to beach conditions. They include low-growing perennials such as seaside primrose, railroad vine, sea ragweed, sea oats, beach madder, and sea purslane. They also include the semishrubs beach plum and bay cedar. Farther back from the water, where low dunes occur, are lantanas, crotons, and woody plants such as necklace pod, Spanish dagger, and sea grape.[38] In many places along the back beach, Australian pine, an introduced species, has displaced the native vegetation. (Figure 29)

Marine grasses cover much of the bay beach just seaward of the intertidal zone, providing food and habitat for many marine species.

Wildlife of the Beachfront: Birds of the sand beaches include: brown pelican (Figure 30), snowy egret, red-breasted merganser, American oyster catcher,* semipalmated plover, piping plover, snowy plover,* Wilson's plover,* blackbellied plover, ruddy turnstone, willet, knot,

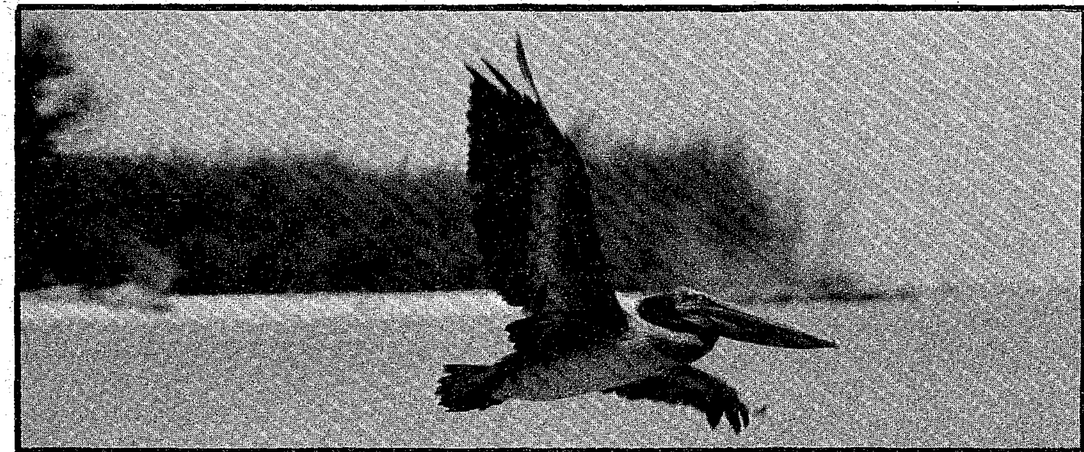


Figure 30.

The brown pelican is one of Sanibel's many endangered species of birds.

least sandpiper, dunlin, semipalmated sandpiper, western sandpiper, sanderling, herring gull, ring-billed gull, laughing gull,* Forster's tern, least tern,* royal tern, sandwich tern, Caspian tern, and black skimmer.*

The loggerhead sea turtle has received more publicity than other reptiles on the beaches of Sanibel, but many other reptiles and amphibians are found on the sand beaches, including: alligator, ornate diamondback terrapin, gopher tortoise, southeast five-lined skink, six-lined racerunner, eastern glass lizard, Florida water snake, southern black racer, eastern coachwhip, indigo snake, eastern diamondback rattlesnake, southern toad, Cuban tree frog, and several species of marine turtles.[39]

Offshore Marine Ecosystem: The offshore marine ecosystem includes 70 species of fish and approximately 400 species of mollusks. They inhabit a range of areas including non-vegetated waters, sea grasslands, algae mats, mangrove roots, rock pilings, oyster bars, and sea walls. The fish and mollusks provide a complex and rich food supply for manatee, dolphin, otter, fish, birds—and man.[40]

The tremendous molluscan population can be attributed to the mosaic pattern of the bottom environment, current patterns, and variations in salinity.[41]

* Nesting on or near Sanibel Island

Figure 31.

Bulkheads like the one shown here cause deflection of sand away from the beach and give a false illusion of security to these condominiums located near the ocean's edge.

Condition of Beachfront

Sanibel's front beach is in good condition. Except for Point Ybel and the Blind Pass area, it is in virtual equilibrium, neither receding nor advancing. This is likely a temporary state, and therefore it should not be inferred that the beach has permanently survived the effects of recent oceanfront development. The placement of bulkheads, condominiums, and commercial structures has created a precarious situation along a considerable portion of the beach. (Figure 31) Serious damage to the beach will occur during hurricanes or heavy winter storms. Wave energy reflected from the bulkheads and buildings will scour a great amount of sand from the upper beach and wash it away. If the waves are sufficiently severe, they may undermine and damage beachfront buildings and bulkheads. (Figure 32) There has not been a severe hurricane at Sanibel since the causeway opened and the development boom began.

The natural restorative powers of the beach have been jeopardized by alteration of the back beach. Development along the beachfront has centered on the frontal ridge (dune) system, the same sand-storage area that naturally stabilizes the beach. The ridges have been flattened for landscape and building purposes. In other areas, the stabilizing vegetation has been destroyed by foot and vehicle traffic. With the dunes removed, there is no sand to replace beachfront supplies that have been washed away. Also, the houses, hotels, and condominiums are exposed to damage by storm waves.

The populations of wildlife species that depend upon the beach environment have declined, some seriously. Many of the former bird nesting areas in the dunes and the back beach have been destroyed. Also, the number of loggerhead sea turtles nesting on Sanibel beaches has declined drastically. Invading Australian pines now constitute a major portion of back-beach vegetation, having displaced plants such as the sea grape and necklace pod. Because of shallow rooting, Australian pines are especially prone to windthrow. The fallen trees and exposed root systems interfere with the movement of turtles to and from the nesting sites.

Shell collecting along the Sanibel beach has declined, but the decline cannot be attributed to changes in the beach itself. It results from the greatly increased number of shellers, which causes more competition for the better shells. The number of shellers visiting the Sanibel beach increased from about 50,000 in 1960, to 250,000 in 1975. (Figure 33) It is possible, however, that the declining abundance of certain prize shells has occurred because of natural or man-induced environmental changes.

The bay beach (on San Carlos Bay from Point Ybel to Woodrings Point) has been receding since the causeway

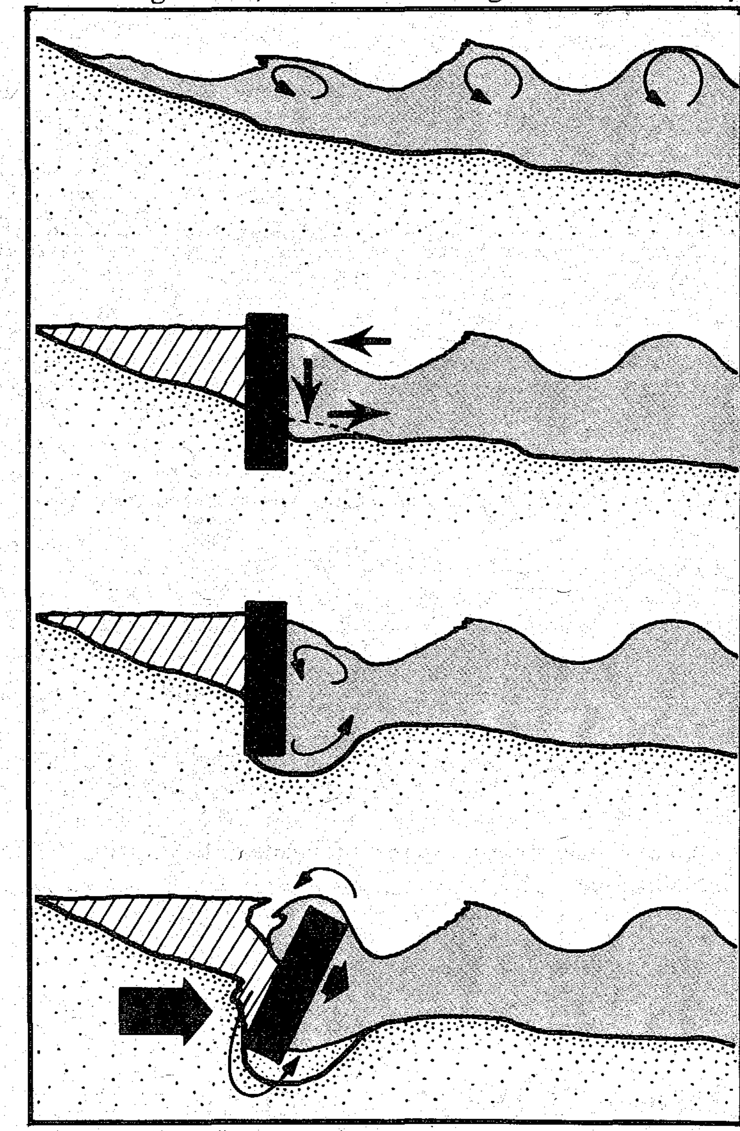


Figure 32.

Bulkheads may be undermined by heavy waves and rendered useless; natural means for shore protection are much more effective.

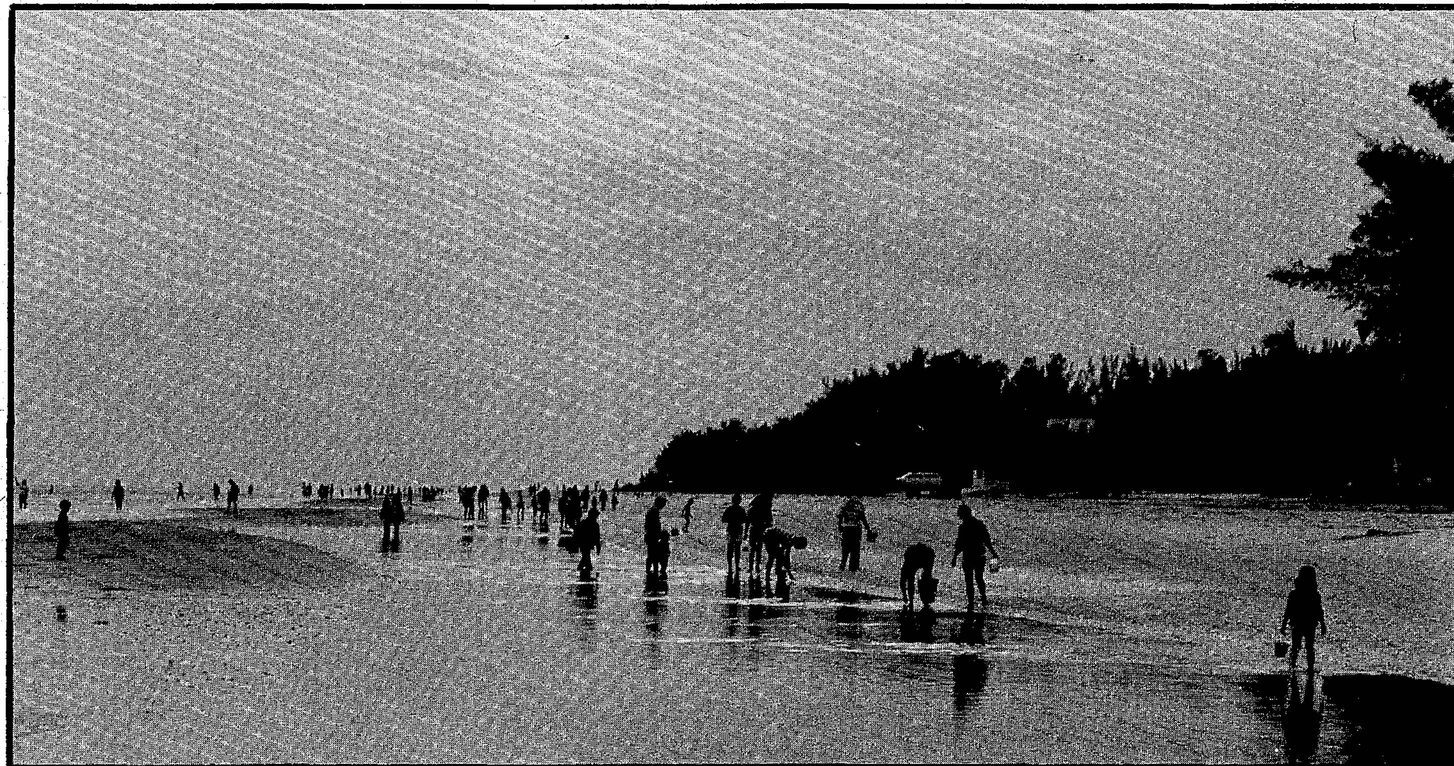


Figure 33.

Hundreds of thousands of persons collect shells on Sanibel beaches.

was built, possibly due to higher water velocity and greater littoral scouring. Like the gulf beach, it has been altered by bulkheads and buildings. Piers and canals have had additional effects. Point Ybel itself appears to be eroding. Management will definitely be required.

The Blind Pass area at the western end of Sanibel is an entirely different case. (Figure 34) The beach and inlet dynamics cause the beach to change form constantly. Long bars and peninsulas are formed, then closed, creating temporarily land-locked lagoons, or bayous. The inlet itself alternately opens and closes. Noticeable changes can occur in only a few years. (See Chapter 7 on Special Zones for a further discussion of the Blind Pass area.)

Management Recommendations for Beachfront Zone

The beachfront policy of the City of Sanibel should be based on the recognition that the beach is an all-important buffer area between land and sea—and that alterations of its natural condition are likely to reduce its ability to function as a buffer. It should be the city's public policy to manage the island's whole beachfront as a unit, so as to restore its natural condition and protect it against further damage. The main thrust of the protection program should be to maintain the beach profile, including prevention of sand removal or any other alteration of any part of the beachfront. (Figure 35)

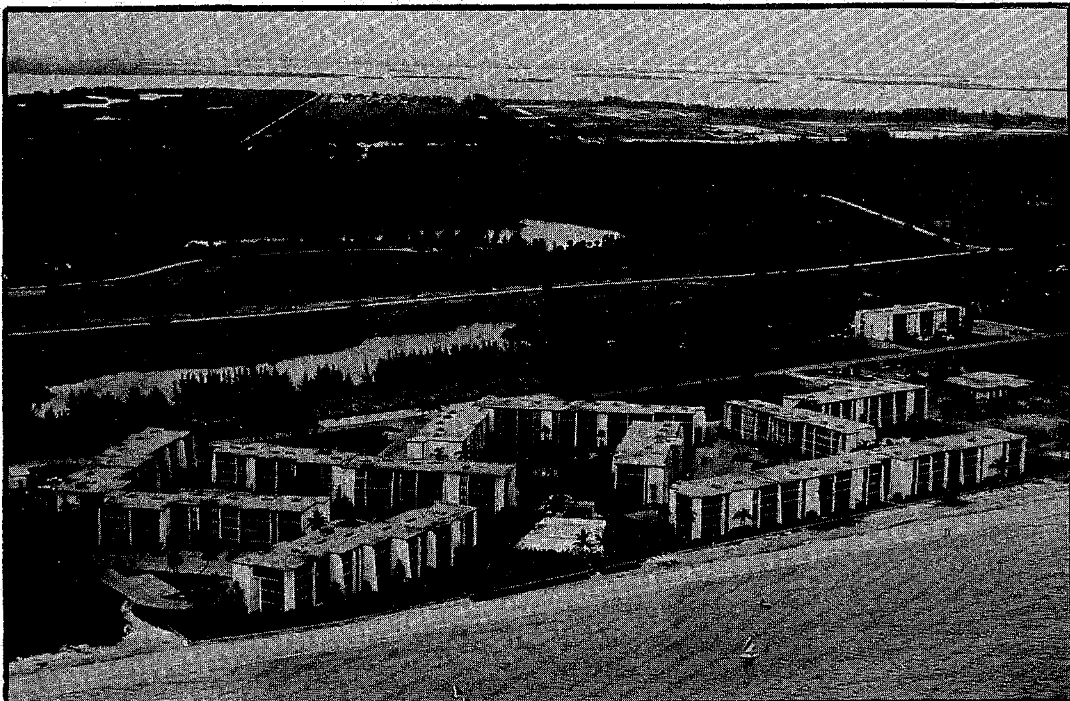
The ocean beach is Sanibel's principal attraction for visitors and residents alike. While shell abundance and diversity have been seriously lowered, the beach itself remains relatively intact. Sanibel's beach has not been subjected to a major hurricane since 1960. Because of extensive beachfront development, the beach is far less able to withstand a hurricane than it was 16 years ago. Thus, in addition to inflicting massive damage to struc-

Figure 34.

The westernmost portion of Sanibel is Blind Pass, an area of shifting sands and unstable shorelands.

Figure 35.

Groins and other structures designed to retain sand on beaches have a disappointing history of failure; management techniques that respect the powers of nature are more effective.



tures, the next major hurricane may well cause extensive and permanent damage to the beach itself. (Figure 36)

The dune ridges are held in place by sea oats, railroad vine, and other dune and beach plants. The fragile network of vegetation growing on shifting dunes is adapted to withstand the rigors of wind, sand and salt—but not human feet or beach buggies and other vehicles. When the mantle of vegetation is broken, the dune movement is accelerated to a point where plant growth cannot keep pace with the shifting sand.

The Conservation Foundation made the following recommendations for protection of the front beach (water's edge to vegetation line) and the back beach (vegetation line inland to the setback line):

1) The city should adhere strictly to the state's ocean setback line of approximately 150 feet inland from the vegetation line of the beach (this is considerably inland of the mean high water line). There should be no bulkheads or major structures of any kind in this buffer area except for boardwalks or other access ways to the beach.

2) A setback line should be defined by the city for the bay beach (from Lighthouse Point to Woodrings Point), using criteria compatible with those applied by the state

Figure 36.

Building on the beach is exceptionally foolhardy because the structures eventually can destroy the beach.

Figure 37.

A setback of 50 to 100 feet is recommended for the San Carlos Bay shore from Point Ybel to Woodrings Point.

for the oceanfront setback. The criteria would dictate a setback of less width (50-100 feet) than the ocean standard since the bayside beaches have lower energy regimes than the oceanfront beaches.

3) Integrity of the beach should be maintained along the whole beachfront. Wherever sand dunes and ridges have been leveled or lowered, they should be restored to their original condition and revegetated. There should be no further grading, excavating, or other alteration of the frontal ridge line.

4) Sand should not be removed from any part of the beach (from the inner edge of the setback line out to the 300 feet jurisdictional boundary of the city), since sand removed for any purpose subtracts from the beach-sand budget and upsets the profile.

5) There should be no removal of native vegetation within the setback area. Sea oats and other natural vegetation are needed to bind and hold the back beach together. (Figure 38) Exotics such as Australian Pine should be removed and replaced with native vegetation to the extent practicable.

6) Any traffic on the frontal sand dune ridge should be discouraged (access to the beach should be by boardwalks over the sand). (Figure 39) Keeping the ridgeline at its highest elevation is essential to eliminate saltwater inundation of the wetland areas during large storms, and to provide the fullest sand storage potential for the beach profile.

Figure 38.

This shore home is built back from the beach, thus preserving the native vegetation and the geologic structure of the beachfront.

Figure 39.

Elevated boardwalks are recommended for crossing beach ridges (sand dunes).

7) There should be no traffic (foot or vehicular) through any part of the setback buffer area in which terns, plovers, skimmers, and turtles breed during the period May through August. This may require preventing trespass into many private property areas. Owners and their guests should cross the area on a single path or otherwise avoid disturbing nesting activities.

8) Means should be taken to ensure that other governmental jurisdictions (such as Lee County or Captiva Island) should not block littoral transport to Sanibel with groins or other structures, nor cut off sand supply to the coast from inland via rivers. Also, the replenishment of beaches on the updrift side should be encouraged to protect Captiva from erosion. (Figures 40, 41)

State and federal regulations can lend important support to Sanibel's beach protection efforts. The state oceanfront setback line has been noted. Federal regulations under the Flood Disaster Protection Act may strongly influence beachfront development.

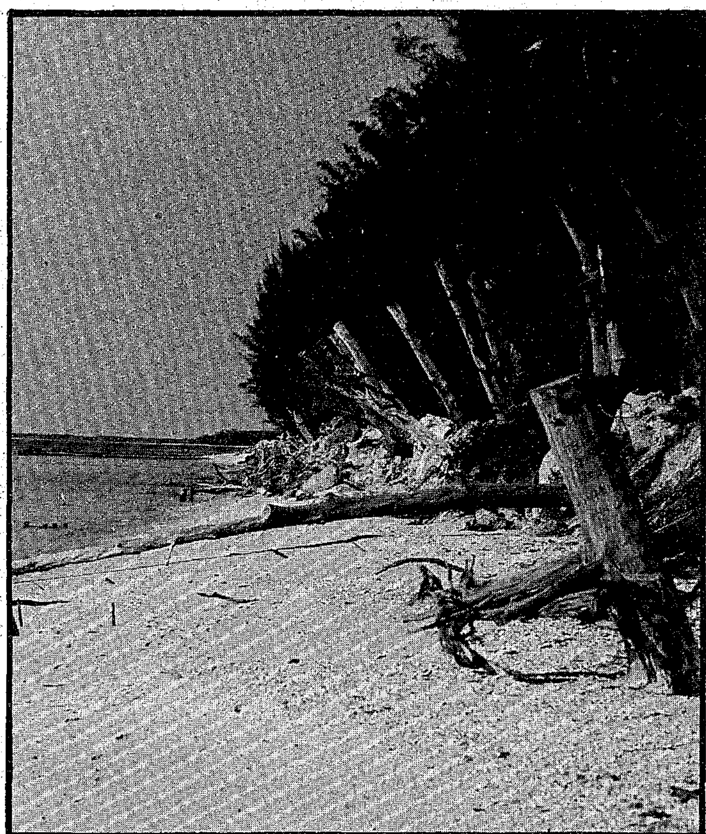


Figure 40.

Captiva Island to the north of Sanibel has lost much of its seafront to erosion; the loss of this valuable buffer zone increases the likelihood of damage from tropical storms.

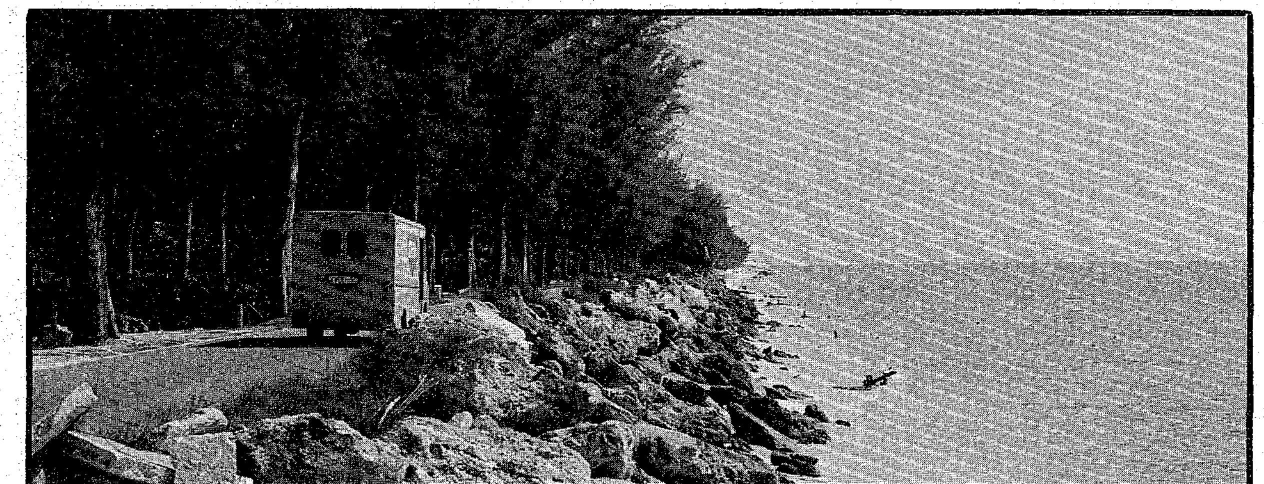


Figure 41.

With the beach on Captiva Island virtually gone, riprap structures must be used to support the road.

CHAPTER 4

INTERIOR WETLANDS

Identification of the Interior Wetland Basin

The Interior Wetland Basin Zone is the interior bowl which serves as a freshwater reservoir. It is composed of parallel systems of ridges and swales with corresponding bands of vegetation. There are two subareas within this zone—lowland and upland. The lowland area is composed of low ridges and wide swales, and it experiences extended periods of flooding each year. The upland consists of higher, broader ridges and narrower swales, and is characterized by less frequent flooding and more upland vegetation types.

Surface Hydrology: Because of the nearly instantaneous infiltration of rainwater, few barrier islands develop a natural type of channelized interior drainage system. Sanibel Island is different in that a partially channelized interior drainage system, the Sanibel River (more accurately a slough), developed rather late in its geologic history. (Figure 42) Beach ridge geometry, variable permeability, and vegetation patterns all contributed to the formation of the Sanibel River at some time during the last 1,000 to 1,500 years of the island's 5,000-year history.[42] Before human alteration, the slough meandered over an irregular course nearly eight miles long. Two subbasins were formed by segments of the slough. The western segment was separated by low beach ridges south of Tarpon Bay from the eastern segment. The system was unified only during the high water stages.

The drainage characteristics of the eastern subbasin differed considerably from the western subbasin.[43] In the east, the "course" of the Sanibel River was straighter, although it transected most of the low ridges at oblique angles. The only "tributaries" to the slough in the east were the natural swales transected by the slough. During low flow conditions, water in the eastern basin moved to the east, and during high water conditions it broke through the Gulf Beach Ridge and discharged into the Gulf of Mexico just west of Point Ybel. In the west, the slough meandered considerably because of the low relief of the ridges. (Figure 43) There were several "branches" to the slough. During low flow conditions, water flowed to the west; and during high water, it broke through the Gulf Beach Ridge and discharged into the gulf at a point about 2.5 miles east of the Blind Pass Bridge. Two other systems drained through mangroves to Pine Island Sound to the north, and through a series of interconnected ponds to tidewater to the west.

The Sanibel River was only a drainage way and never a true stream. Flow occurred only during times when the

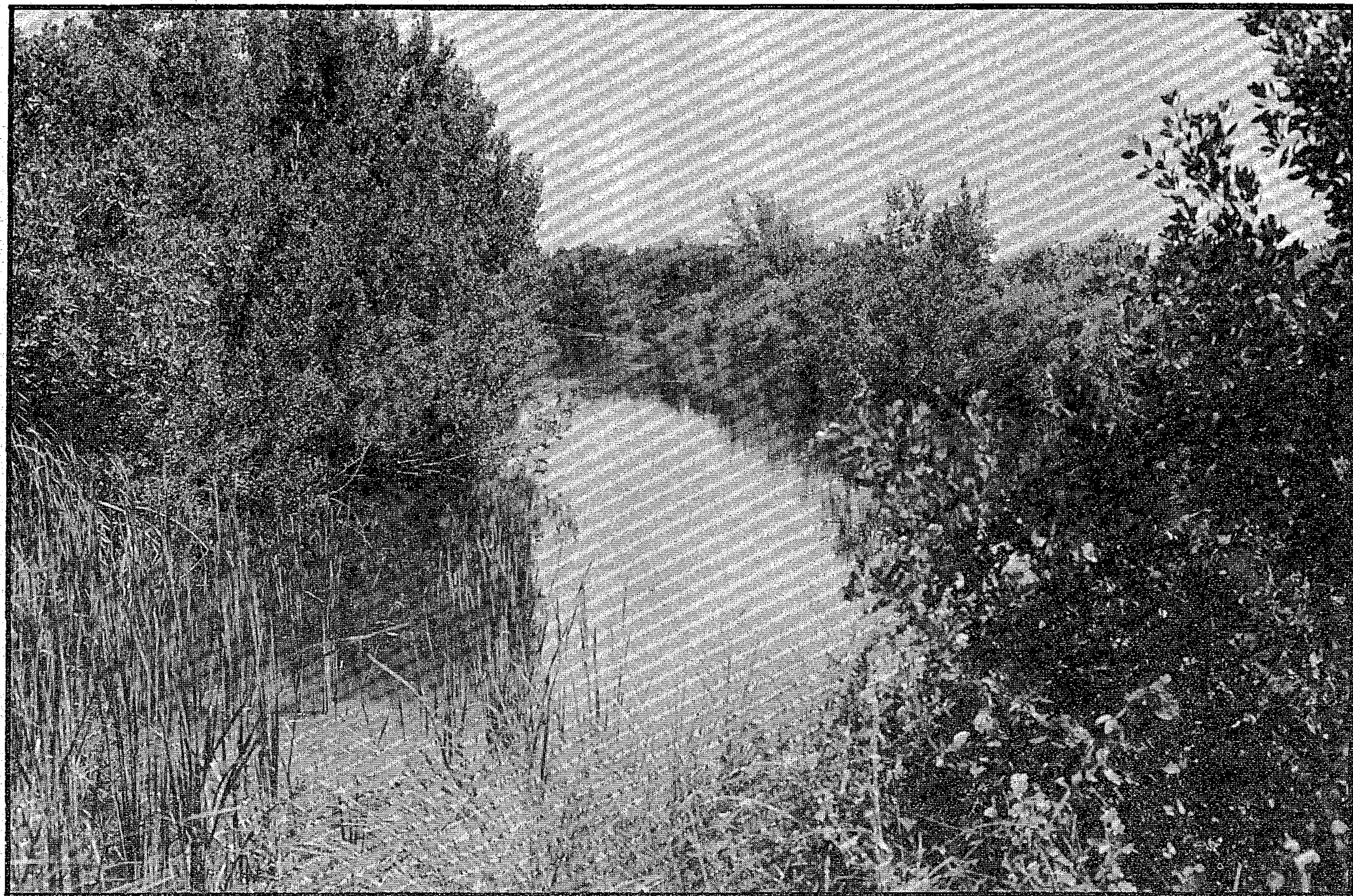


Figure 42.

The Sanibel River is central to the island's ecosystem and this water system makes Sanibel unique among gulf coast barrier islands.

water table was high and infiltration of precipitation was inhibited. Under original conditions, the storage curve probably would have risen very slowly during May, June, and July because of spotty, generally light rains.[44] In August through October, the generally heavier rains fell on a reservoir whose storage capacity was reduced substantially by fall high tides. If rains were sufficient, as they probably were nearly every year, washout occurred. If less substantial, the rise in interior storage would terminate in mid-to-late October and then decline through seepage and evapotranspiration until the next rainy season. Tabb estimates that in the eastern system 14.4 inches of rain could have raised the water table to four or five feet above mean sea level before washout.[45]

This freshwater drainage and storage system spawned the development of many wetland communities which depend on the seasonal changes and freshwater recharge to hold back the intruding saline waters.

Soils: Soils of the Canaveral series have developed in the interior basin. They consist primarily of organic deposits over sands. Tabb found surface deposits of calcium carbonate soils (called marl) to be an important constituent in swale-bottom soils. These soils are formed in shallow water under conditions of intense sunlight, high temperature, and rapidly fluctuating dissolved oxygen and pH.[46] Tabb also found a well-developed lens of limy material. This may be hardpan, derived from precipitation of organic material and minerals in solution at the contact between the water table and overlying oxygenated sands. Tabb wrote: "If this is true hardpan, then it may represent the long-term position of the water table during the dry season of pre-drainage times and thus an interesting reference point for discussion of future water management because it would suggest that the water table seldom fell out of direct contact with the marl of the swales."[47]

Several properties of the marl-rich soils are important. Periodic saltwater saturation of these soils raises the pH to a level where normal nitrification halts at the nitrite stage. Toxic amounts of nitrite may accumulate with application of ammonium fertilizers or sewage effluents.

Marl also has the ability to seal otherwise porous soil, thus impounding surface waters and retaining moisture. Such marls probably were important in maintaining the hydroperiod, providing shallow but intermittent ponding, and maintaining soil saturation between shores. This has important ramifications for the floral and faunal communities inhabiting the zone.

Vegetation of the Interior Wetlands: Twenty years ago, the low interior wetlands were open, grassy, and essentially treeless. Vegetation patterns were controlled by natural factors including wind, water-table level, salinity, and elevation of the land. Because Sanibel has a periodically brackish water-table aquifer, almost all plant species are at least partially salt tolerant. *Spartina bakerii,* the principal interior wetlands plant, requires seasonal flooding with fresh to brackish water. This ability to prosper under a varying salinity regime permitted the cordgrass *Spartina* to become the dominant plant community on much of the wetlands. In association with the cordgrass were sawgrass, bead grass, water-hyssop, and sea purslane.

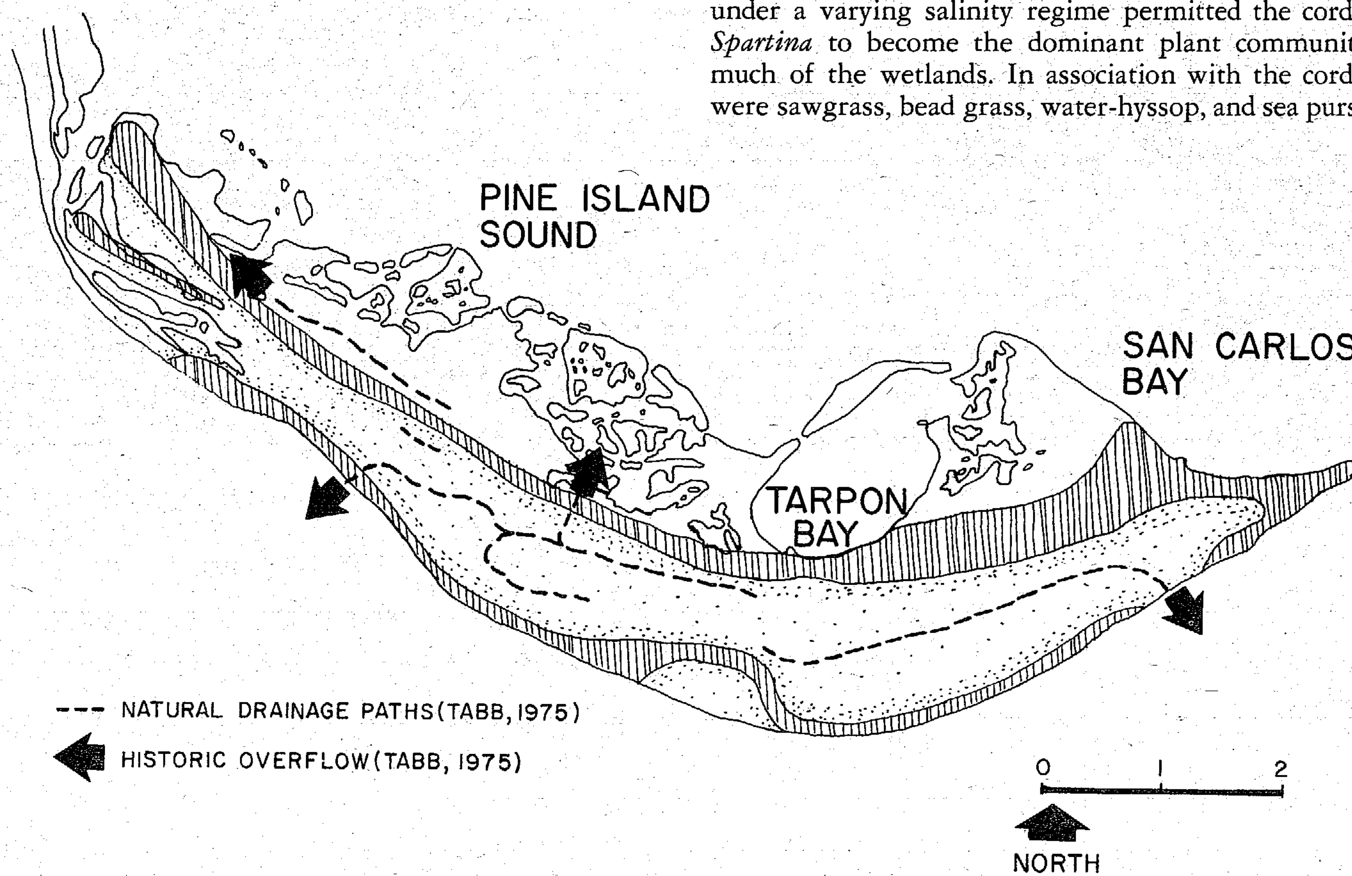


Figure 43.

Historic drainage patterns in the Sanibel interior wetlands; during flood periods water broke through the two main ridges in the four locations shown.

On the almost imperceptible elevations were salt bush and a number of grasses and perennials, and cabbage palms were evident on the highest ridges.[48]

Today, along the Sanibel River and in low swales, the buttonwood-wax myrtle-sea oxeye association is very evident. Also appearing in the swales are cordgrass, sawgrass, andropogon, water-hyssop, cattails, spatterdock, hydrilla, chara, duckweed, and wigeongrass. Cordgrass is still common, though covering a much smaller area than it once did. (Figure 45)

A number of these species have high food value for ducks and birds. Wigeongrass, a submerged aquatic found in both the river and ditches, is a major source of food for

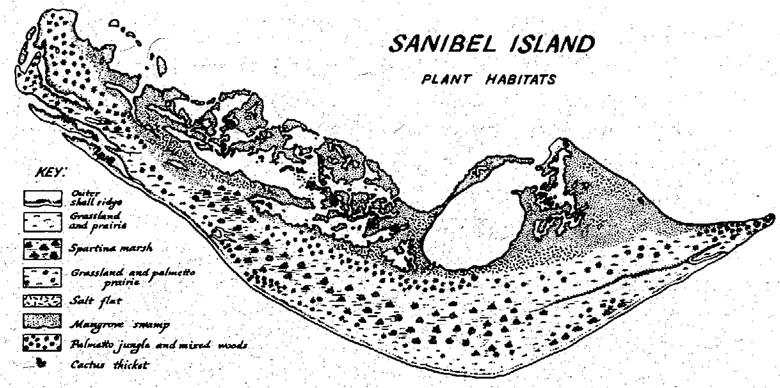


Figure 44.

The original main ecological areas of Sanibel (Source: Cooley).

Figure 45.

Lack of proper water management has permitted various shrubs to infiltrate the open cordgrass meadows and endanger the entire interior wetlands subecosystem.

waterfowl. Cordgrass provides edible roots and seeds for rails, songbirds and ducks and, to a lesser extent, sandpipers. Purslanes disseminate an enormous number of seeds which are eaten by songbirds and rodents. Cabbage palm provides fall fruit for robins, warblers, woodpeckers, fish crows, and raccoons.

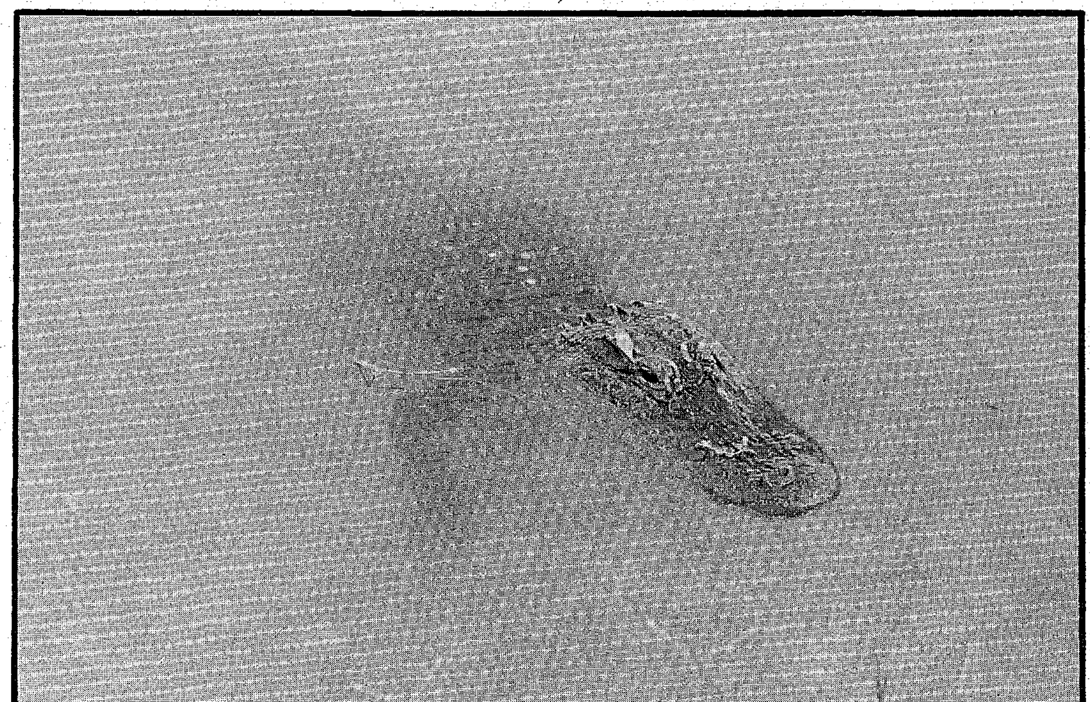
Many of these plants also provide refuge in the form of an almost impenetrable barrier to human and animal hunters. Sawgrass, with its sharp-edged leaves, provides a sanctuary for ducks, as well as supplying a limited amount of food. Cattails serve as roosts and nesting areas for birds and fish.[49]

Native vegetation of the low ridges includes marsh elder, cordgrass, leather fern, wax myrtle, and cabbage palmetto. The Brazilian pepper, a noxious weed, is rapidly dominating many areas in the interior basin.

In addition to the previously mentioned food and habitat functions that the interior wetland vegetation provides for wildlife, it serves important hydrologic functions. The grasses and low shrubs slow runoff, preventing high peak flows and allowing more freshwater recharge. The microflora also greatly aid in maintaining and improving water quality in the wetlands.

Figure 46.

The few dozen alligators left on Sanibel are one of the island's major tourist attractions.



Wildlife of the Interior Wetlands: Ten species of aquatic birds nest in the interior wetlands, and six more are known to frequent them. The area also serves as an alternate refuge for a number of species which normally reside in or visit the saline mangrove areas. Aquatic birds of predominantly freshwater habitat include: pied-billed grebe,* anhinga,* least bittern,* American bittern, mottled duck,* blue-winged teal,* king rail,* Virginia rail, sora, common gallinule,* killdeer,* spotted sandpiper,* common snipe, belted kingfisher, long-billed marsh wren,* and swamp sparrow.[50]

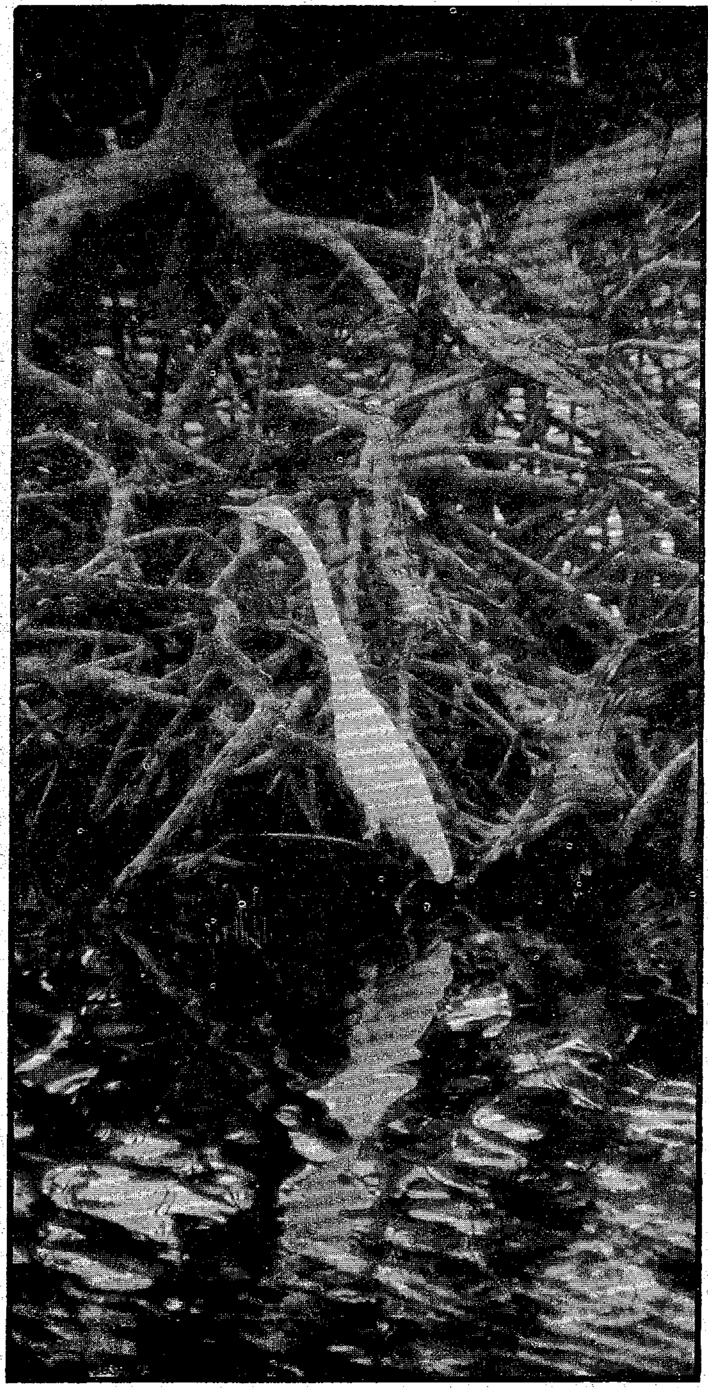
Although alligators are Sanibel's most spectacular aquatic animal, there are many other important reptiles and amphibians of the interior wetlands. Aquatic reptiles and amphibians include: alligator, snapping turtle, striped mud turtle, Florida mud turtle, Florida box turtle, red-bellied terrapin, yellow-bellied terrapin, peninsular cooter, Florida chicken turtle, Florida soft-shelled turtle, common iguana, green anole, southeast five-lined skink, Florida water snake, Florida brown snake, southern ribbon snake, southern ringneck snake, southern black racer, eastern coachwhip snake, indigo snake, yellow rat snake, eastern diamondback rattlesnake, southern toad, green tree frog, squirrel tree frog, Cuban tree frog, southern leopard frog, pig frog, and eastern narrow-mouth toad.[51] Mammals of the interior wetlands are listed on page 74.

Small, freshwater animals are abundant here, and provide food for many creatures. Insects also are abundant, as are crayfish and mussels in varying quantities. Mullet, tarpon, *Gambusia,* bream, bass, and garfish live in the river and provide a bountiful feast for anhingas, crows, ibises, herons, egrets, gallinule and stilts.[52]

Condition of the Interior Wetlands

Aerial photographs of Sanibel in 1944 show the interior wetlands as broad grassy meadows, with shrubs and trees found only along the two major ridges. Since the 1940's,

* Nesting on Sanibel Island



man has altered the physical character and vegetative patterns of the wetlands in three major ways: 1) physical alterations, such as clearing, filling, lake excavation, and flattening dunes; 2) alterations of the hydraulic system, including drainage, channelization, and impervious paving; and 3) introduction of exotic plant species which, due to their hardiness, have crowded out the native vegetation.

Each alteration has interfered with the ecological integrity of the wetlands, and of the island ecosystem. By modifying the native plant, animal, and water systems, the historic habitat diversity has been reduced. The vegetation of the Sanibel wetlands is continuing to undergo rapid change. Major losses have occurred to cordgrass and sawgrass. Together these two species provided both food and refuge for ducks, song birds, and mammals.[53]

The most important alteration of the interior wetland system has been the lowering of the water table. Before the dredging of the Sanibel River and the installation of the water-control structures, the water level fluctuated from slightly below mean sea level (MSL) to five feet above MSL during floods. Water levels changed with every rainfall, often raising the water table two to three inches for each inch of rainfall.[54] The two control structures at Tarpon Bay and Beach Pond have reduced fluctuations in water level by setting the maximum water level in the interior at heights varying from 2 to 3 feet above MSL—water control structures are now set at 2.5 feet above mean *low* water.

Construction of canals and drainage ditches has had a pronounced effect upon the water table over large areas of the island. The deep tidal canals at the eastern end of the island have permanently lowered the water table. Canals have been spaced so closely on some parts of the island that the water table probably does not range much above sea level.[55]

Road building and mosquito ditching have altered drainage pathways considerably, replacing a system of gradual runoff by one given to greater extremes of flooding and drought. (Figure 48) This system—though less efficient than a purely natural system—does allow downward percolation of fresh water for storage, and it acts as a sponge for increased water levels during the wet summer season. Historically, when flooding occurred its duration

Figure 47.

Sanibel's water birds are dependent upon the values of the mangrove subecosystem.

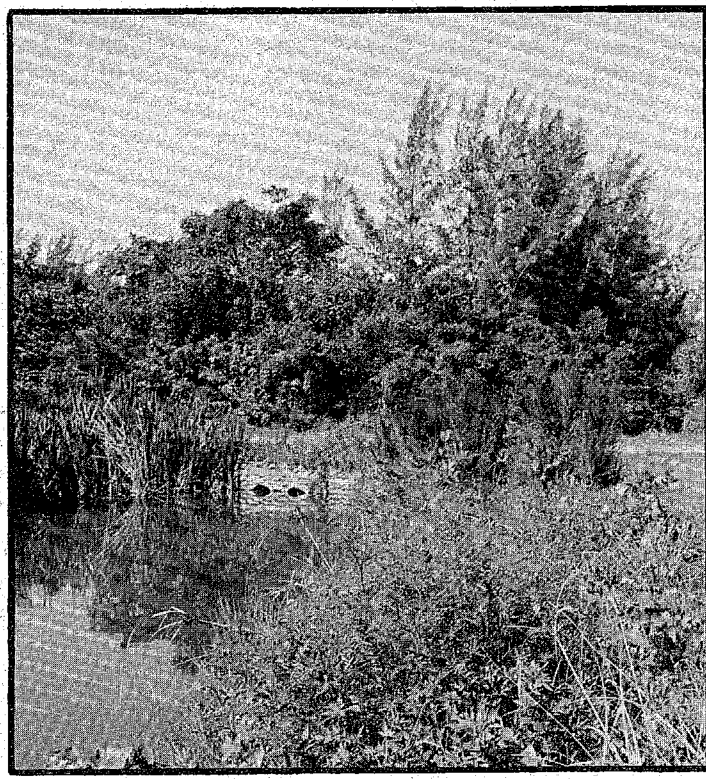


Figure 48.

In wetlands areas, roads and ditches with inadequate provisions for water flow cause serious loss of wildlife habitat and can harm other ecological values as well.

was brief—excess water passed easily over beach ridges to the gulf.[56]

The altered interior drainage system has caused a rapid recession of water levels during the dry season. The control structures at Tarpon Bay and Beach Road are not adequate, leaking water both in and out. Evaporation losses also have been increased because of the additional amount of exposed surface water. In short, water-control devices which were built to control water level are allowing too much water to leave the wetlands. As a result, the water table has been lowered, damaging native vegetation.[57]

The high permeability of Sanibel's soils results in direct contact between rainfall and the water-table aquifer. Many factors control the natural water system, such as the duration of rainfall that replenishes the groundwater supply. This freshwater replenishment cycle competes with salt water, which quickly replaces depleted fresh water. The constant push and shove between fresh and salt water makes preservation of the freshwater replenishment cycle a major consideration in any future development of the island. A reduction of fresh water in the system will result in greater quantities of salt water—a phenomenon detrimental to water quality.

The plan for controlling mosquitoes on Sanibel, as initially conceived, was ingenious—but it was never successfully implemented, and problems have persisted. Lowered water levels in the interior wetlands favor mosquito-breeding. The control system, which has had little maintenance since the early 1960's, was never completed as designed, and has been disrupted by roadway blockages. Lack of enthusiasm for water management and biological control of mosquitoes, and emphasis on toxic chemical control by the county, have contributed to the deterioration of Sanibel's control system. The insecticides in use on Sanibel appear to be highly toxic and therefore potentially damaging to wildlife. For example, recent unpublished tests appear to show the principal insecticide, fenthion, to be toxic to aquatic species in concentrations of fractions of parts per billion. What may have saved Sanibel's wildlife from greater past damage is that fenthion seems to evaporate when it is heated by the aircraft's exhaust system (along with diesel oil, the application medium). Thus, the fenthion may evaporate while the oil falls and itself becomes the effective anti-mosquito toxin.

Water quality in the Sanibel River and other parts of the interior drainage system varies considerably. The salinity of the water in any particular segment of the system is controlled by climatic factors, proximity to a source of saline-water leakage, the quality of water in adjacent parts of the water-table aquifer, and the characteristics of the drainage way. Heavy nutrient influx, stagnation, and deposition of organic detritus all degrade the general quality of the water.[58]

Salinity varies seasonally with recharge and discharge. In most parts of the surface-water system, chlorides decrease during the wet season as a result of flushing and dilution by rainfall. In some parts of the Sanibel River, high-chloride water at the bottom is trapped because of bottom irregularities.[59] The trapped water decreases in

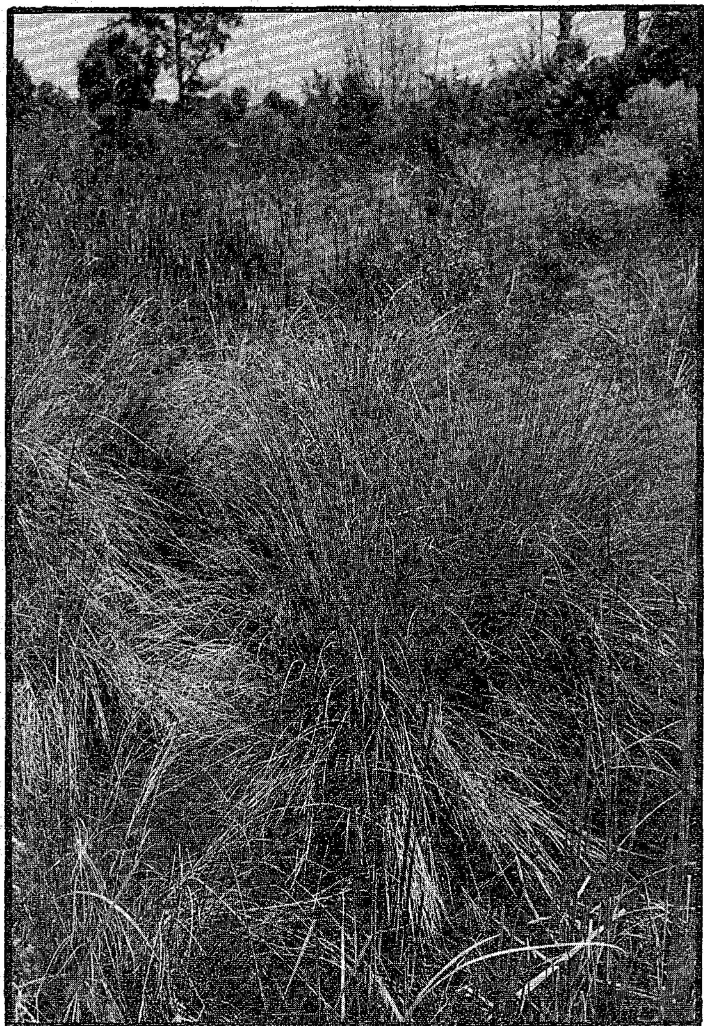


Figure 49.

Cordgrass (Spartina bakerii), the dominant plant of the interior wetlands, occurs in large clumps when there is sufficient water at its roots.

chlorides only by dilution, which occurs during periods of high water. Chlorides increase during the dry season because evaporation and evapotranspiration losses cause concentration of dissolved solids.

The vegetative zonation of the interior wetland is determined by a combination of water level and salt tolerance. *Spartina bakerii*, the naturally dominant wetland plant, prospers with alternative flooding of fresh and brackish water. (Figure 49) The saw palmetto is often found in the transition zone between upland and wetland areas, and is a useful indicator for delineating the two zones. The original patterns, however, have been seriously altered. Because of a lowered watertable, *Spartina* areas are easily invaded by upland woody plants and exotics such as Brazilian pepper. These quickly reproduce and replace large areas of native vegetation.[60]

The Brazilian pepper became popular as a landscape shrub in Florida in the mid-1950's. Today, it is out of control in many areas. On Sanibel it has produced a closed canopy over much of the abandoned farmland on the eastern part of the island. It has become dominant in the interior wetlands where it outcompetes *Spartina* for sunlight. The Brazilian pepper can also cause itching, rashes, sneezing, and severe sinus congestion. The appropriate nonchemical control is cutting and removal—new sprouts in a *Spartina* marsh renovated in this manner could be controlled by burning.[61]

The wildlife-carrying capacity of the island's interior wetlands has dropped considerably. For example, increasing salinity, excavation, and perhaps pesticides appear to be lowering the populations of birds, reptiles, and amphibians. Raising the water table and increasing the storage capacity of the water-table aquifer will lower the salinity intrusion, and might boost wildlife populations.[62]

General Wetlands Conservation

The Conservation Foundation recommended the following general conservation practices:

1) As a general rule, there should be no excavation in wetlands for the following reasons: Vegetation would be obliterated; water flow disrupted; soil layers destroyed; pollutable catchments formed; and drainage and drying out of wetlands facilitated. Accordingly, excavation should take place only when required for essential public purposes (mosquito control or wildlife enhancement, for example) and should be limited in extent (not more than 10 percent of the area).

2) Generally, there should be no filling of wetlands. The soil cover would physically obliterate the wetlands and disrupt their function as completely as excavating them would.

3) Generally, there should be no land clearing, grading, or removal of natural vegetation, since vegetation is an

important element of wetlands function. An exception should be made, however, to permit control and removal of noxious exotic plants (such as the Brazilian pepper) and other undesirable invader species (shrubby plants) in the interior wetlands. These should be removed mechanically or by controlled burning.

4) Discharge or release of pollutants into the wetlands should be prevented. There may, however, be some capacity for the wetlands to absorb certain storm-runoff pollutants and thereby function as a "land treatment" system. Any such pollutants should not exceed the calculated receiving capacity of the system and should not degrade surface water or groundwater below allowable standards.

5) There should be no solid-fill roads or similar structures in wetlands because they obstruct water flow. Also, fill for any such structures must normally come from excavation, which is in itself damaging. If some roadways do become necessary, they should be elevated on pilings rather than placed on fill.

Management Recommendations for Interior Wetlands

It should be the public policy of the City of Sanibel to ensure that wetlands remain functionally intact. Whatever their use, they should not be altered in ways that would degrade their natural function.

Lower, or low-ridge-and-swale, wetlands are found principally in the interior basin. They occupy roughly 60 percent of that basin. Some low-ridge-and-swale areas have been considerably altered, but a restoration program should return them to good health.

High-ridge-and-swale sections of the interior wetlands basin are characterized by cabbage plum hammocks. The principal plant indicator of the swales is *Spartina,* but other marsh plants may also identify the swales as significant wetland plant communities. A number of the ridges appear to be wide enough and sufficiently elevated above seasonal high water levels to be developed for housing. However, the interridge wetland swales in the high-ridge-and-swale areas should be protected following the same general standards given previously for low-ridge-and-swale wetlands.

Residential development of the ridges (high-ridge-and-swale) can proceed without degrading the interridge wetlands swales, although care will be needed to assure that the swales are preserved.

To protect the swales, as well as to maintain water quality and satisfy other environmental requirements, residential development of high ridges will undoubtedly have to take a new form. Along the narrower ridges, houses should be laid out in narrow rows. Access roads should be bridged over the interridge swales.

Hurricane protection requirements will also affect housing style. Most of the high ridges will be covered by 5 to 7 feet of water when Sanibel is inundated by the predicted 10- or 12-foot surge of water from an intense hurricane. Therefore, all houses on the ridges will probably have to be elevated on stilts five to seven feet above natural ridge elevation to meet federal flood insurance requirements. (Figures 50, 51).

Acceptable Uses: As the above constraints suggest, the natural characteristics of wetlands are such that the preservation of their functional integrity precludes virtually any development within the cordgrass portions. Roads through wetlands are not adequately controlled by regulations. A great deal of ecological damage has already been caused by public and private roads that cut through such areas on the island. Specific requirements should be given to prevent water blockage and other disturbances from roads. Minimum elevations should be established to facilitate evacuation.

Recreational use of wetlands would be enhanced by the installation of light-duty, elevated (pile-supported) structures such as blinds, catwalks, piers, and similar open structures. (Figure 52) If properly controlled, these should not have a major detrimental effect on water systems and estuarine resources. Nevertheless, even these should be designed and built to cause minimum impact by shading, water-flow interruption, and site disruption. They should be elevated above the 10-year flood-return height and should have very low ground coverage (no more than about 0.5 percent surface alteration). Any area disrupted when installing these facilities should be fully restored to its natural condition.

Restoration of Wetlands: Protection of wetlands, though essential to prevent future disruption, is insufficient to undo damage already done. For that, a restoration

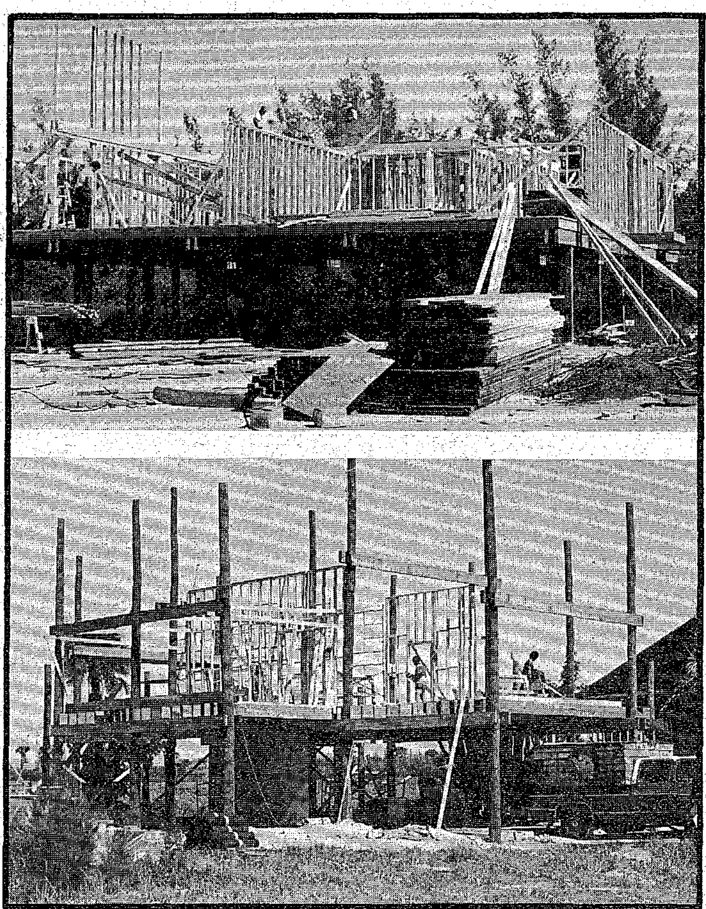


Figure 50.

Two types of elevated homes under construction: platform-elevated type (above); piling hung type (below).

program is needed. Because of past abuses there is considerable need for restoration of Sanibel's interior wetlands.

A restoration program for interior wetlands could provide additional benefits of water supply, water quality, mosquito control, fire protection, and wildlife habitat. The Conservation Foundation made the following recommendations:

1) Return the water systems (that is, water levels, flows, etc.) to as near their original state as possible, and remove all significant existing obstacles to the passage of water in interior wetlands.

2) Take all practical measures to prevent saltwater intrusion of interior wetlands.

3) Remove all exotic and adverse local vegetation that has invaded the wetlands.

Relevant Federal and State Regulations and Policies: Interior wetlands are protected by a number of federal and state laws, regulations, and policies. Most critical, perhaps, are the federal regulations adopted July 25, 1975, under Section 404 of the 1972 Federal Water Pollution Control Act. These regulations require a permit from the Army Corps of Engineers for any excavation or filling of designated wetlands. Although permits must satisfy many criteria, the thrust of the program is to discourage wetlands destruction, as the following quotation from Corps

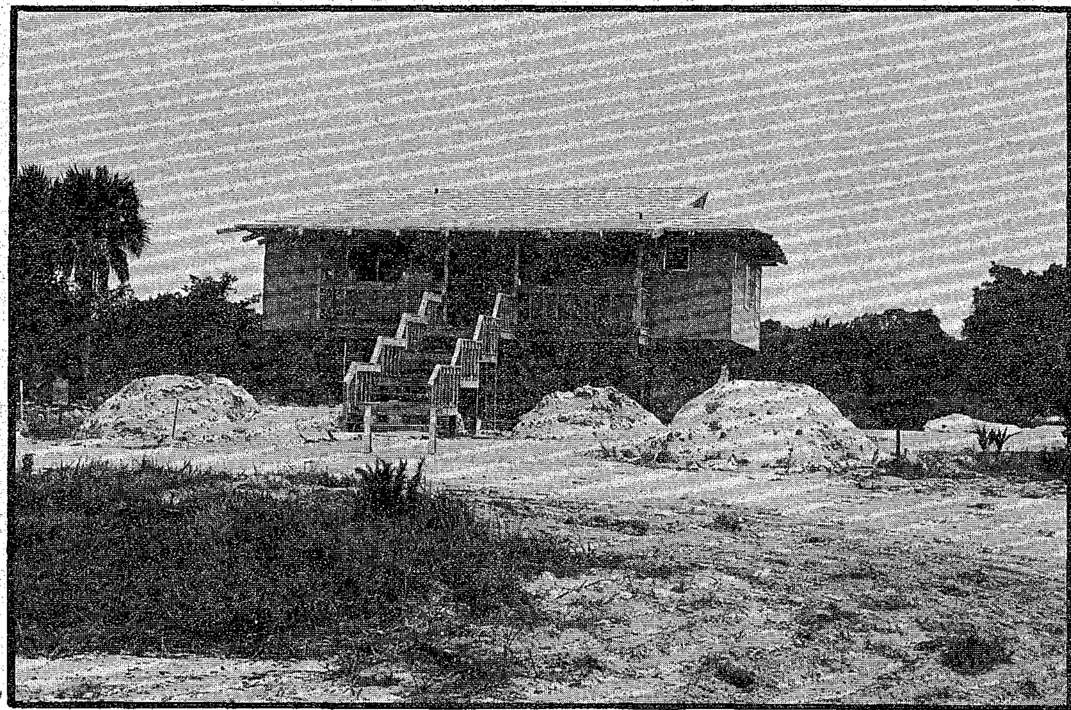


Figure 51.

A completed example of a platform-elevated home.

regulations demonstrates: "As environmentally vital areas, [wetlands] constitute a productive and valuable public resource, the unnecessary alteration or destruction of which should be discouraged as contrary to the public interest." Federal regulations may mean a virtual end to residential development of wetlands.

On October 3, 1975, the Army Corps of Engineers advised the city that it intended to exercise regulatory

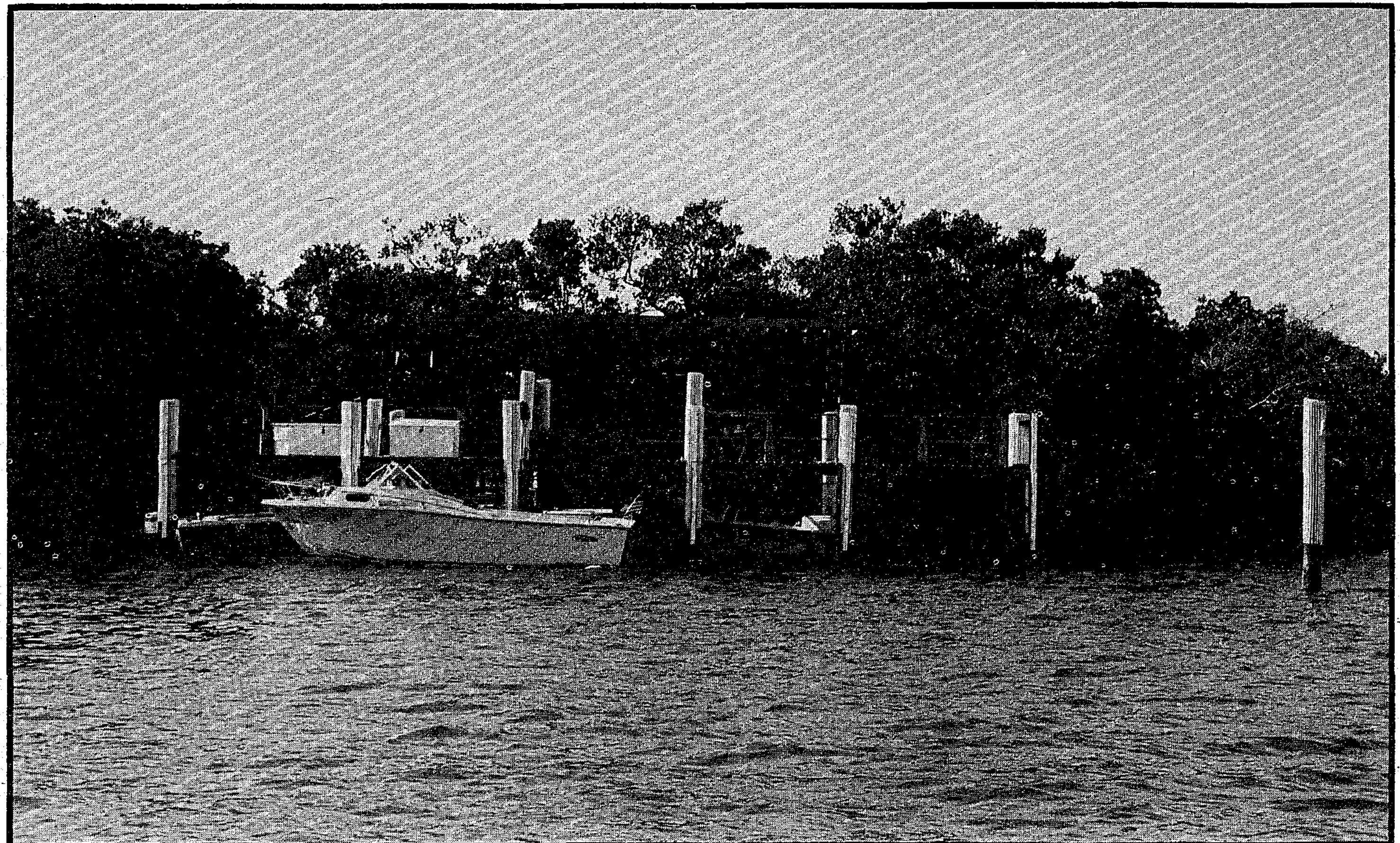


Figure 52.

Properly designed elevated ramps, walkways, and piers enable people to use wetlands without harming them; the walkway and pier shown permit owner to cross between house and boat.

jurisdiction over the Sanibel wetlands under Phase I of Section 404 of the 1972 Federal Water Act. This means that every project proposed for the interior wetlands must have a permit from the Corps, and will be reviewed by the U.S. Fish and Wildlife Service, the National Marine Fisheries Service, the Environmental Protection Agency, and other federal offices. Also, the provisions of the National Environmental Policy Act will be invoked. All this machinery is aimed at eliminating the alteration or degradation of wetlands.

As already noted, the development of Sanibel's high ridges will also be affected by federal regulations intended to reduce the disastrous consequences of hurricane flooding. These regulations, adopted by the Department of Housing and Urban Development pursuant to the Flood Disaster Protection Act of 1972, press localities to require that the first floors of all new residences be built above the 100-year flood level, and that fill may not be used to elevate houses in coastal "high hazard" areas.

Federal and state actions, though strongly supportive of local protection efforts in Sanibel, fall short of providing all needed protection. The city needs to provide protection of water supply, water quality, and wildlife habitat.

There are virtually no relevant federal or state regulations to assist in restoration efforts, although the county mosquito control program does involve water management action on the island.

CHAPTER 5

MANGROVES

Identification of Mangrove Zone

The Mangrove Zone includes all areas of red, black, and white mangroves, as well as the tidal flats and hardwood hammocks within them. Much of this zone, including all areas of red mangrove, is subject to daily tidal flooding. Other areas of the zone are subject to extended periods of flooding every year.

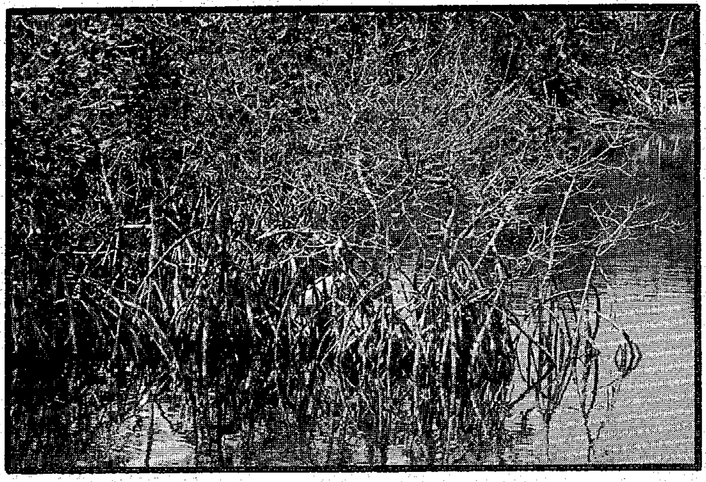
Surface Hydrology and Soils: The lower Mangrove Zone (red mangroves) is inundated daily by high tides; most of the upper zone (black mangroves) is flooded on spring tides; and the entire zone is seasonally or annually flooded. Even the slightest amount of storm flooding will totally inundate this zone.

Peat deposits and salt flats are building up because of trapping of sediments by the vegetation and a rising sea level.

Vegetation in the Mangrove Zone: Mangroves grow on the bayside of Sanibel Island and in the bayous at the west end of the island. They are usually found wherever the shore is tidally influenced and protected from ocean waves. Dominant species include the red, black, and white mangrove, and the buttonwood.

Although a mixture can be found in each area, the red mangrove commonly grows at the lowest elevations where its prop roots experience daily flushing and brackish water. Just inland of this, a mix of understory reds and larger black mangroves proliferates. Subject to frequent flushing, these are particularly affected by storm tides. High black mangroves are flooded during seasonal rains and tides. Here a shrub layer develops, populated by saltwort and glasswort. At the highest elevation along the estuary, where water is confined by natural features, a mixture of black, red and sometimes white occurs. These trees seem to thrive in standing water and are adversely affected during periods of drought. Buttonwood also occurs on the higher elevations. Because of the nature of the substrate and due to very low light conditions, only special plants can coexist here. Algae, fungi, some halophytic shrubs, and many epiphytes thrive.

Mangroves form dense, almost impenetrable thickets which buffer the physical forces of storms. They clean water by trapping silt, nutrients, and toxic substances, and they prevent land erosion. More importantly, they play a leading role in providing wildlife habitat (Figure 53), and in the general ecological productivity of the island. The mangrove system is the critical feeding and breeding area for many shore birds, reptiles, and amphibians, and certain



mammals. All the mangrove species contribute to the food chain, although their contribution is not always immediately available. For example, black mangrove-generated nutrient is flushed into the estuary during late summer and fall, and becomes part of the mosquito-fish-bird cycle.

Heald and Tabb describe the flow of energy provided by mangrove detritus at the basic level: first traveling through bacteria and fungi, then through approximately 12 species of crustaceans, and finally to a number of important sport and commercial species of fish which act as top carnivores.[63]

The mangrove intertidal zone, with its nearby shallow estuary, is a prime nursery and feeding ground for marine species such as shrimp, mullet, snapper, red drum, and blue crab. It is also an excellent fishing area. Tarpon and snook, both dependent on mangrove systems, are the most renowned fish in the area. Mangrove snapper, redfish, and spotted sea trout are also sportfishing favorites.

Wildlife in the Mangrove Zone: The mangrove forest and bays serve as one of the richest bird habitats on the island. Twenty-one nesting species, as well as six migrants, have been listed by Hewitt. Aquatic birds of predominantly saltwater habitat include: brown pelican,* double-crested cormorant,* great blue heron,* great egret,* green heron,* snowy egret,* Louisiana heron,* black-crowned night heron,* little blue heron,* yellow-crowned night heron,* white ibis,* roseate spoonbill, lesser scaup duck, red-breasted merganser, bald eagle,* osprey,* clapper rail,* American oyster catcher,* piping plover, snowy plover,* Wilson's plover,* black-bellied plover, ruddy turnstone, eastern willet,* laughing gull,* least tern,* and black skimmer.*

*Nesting on or near Sanibel Island

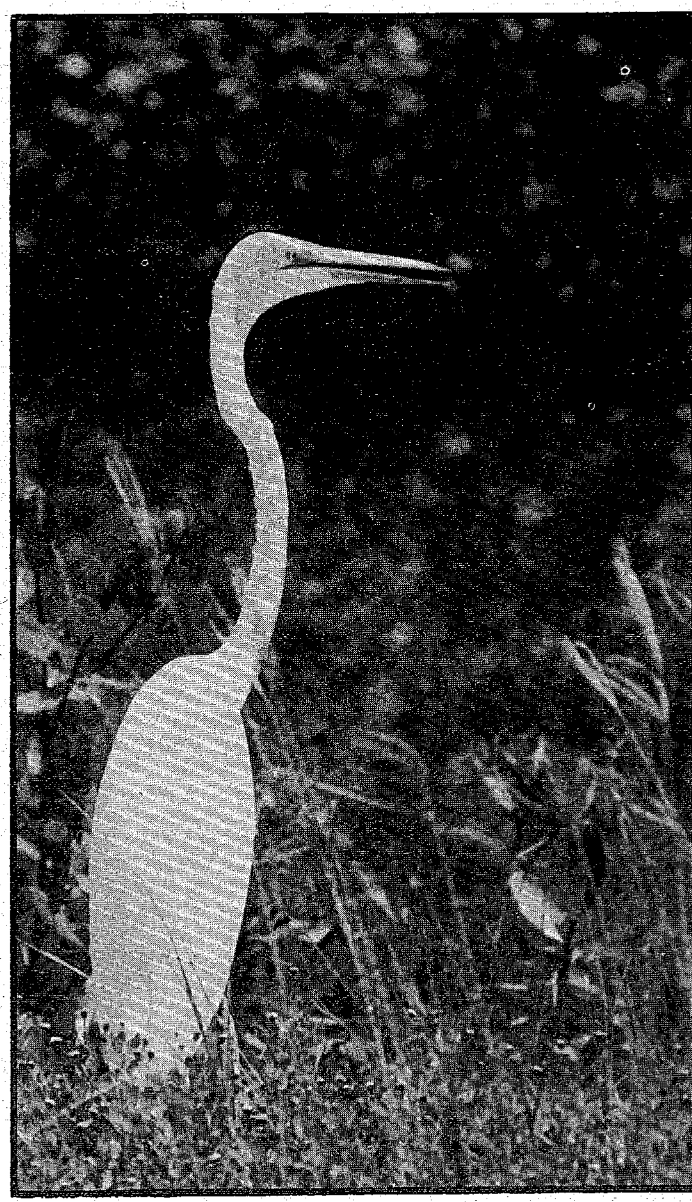


Figure 53. (far left)

Mangrove forests should be protected because they provide a multitude of natural values, including habitat for water birds such as the egret hiding in this photo.

Figure 54. (near left)

Mangrove creeks are important feeding areas for egrets and other water birds.

Several reptiles and amphibians are part of the mangrove food web. Tidal wetland reptiles and amphibians include: alligator, crocodile, ornate diamondback terrapin, green anole, mangrove water snake, yellow rat snake, and eastern diamondback rattlesnake.[64]

Most of the mammals of Sanibel can be found in the mangrove zone at times (see page 74).

Condition of the Mangrove Zone

Conservation Foundation consultants estimated that 2,800 acres of mangroves exist today, the major portion of which (2,300 acres) is located in the J. N. "Ding" Darling National Wildlife Refuge.

Figure 55. (below)

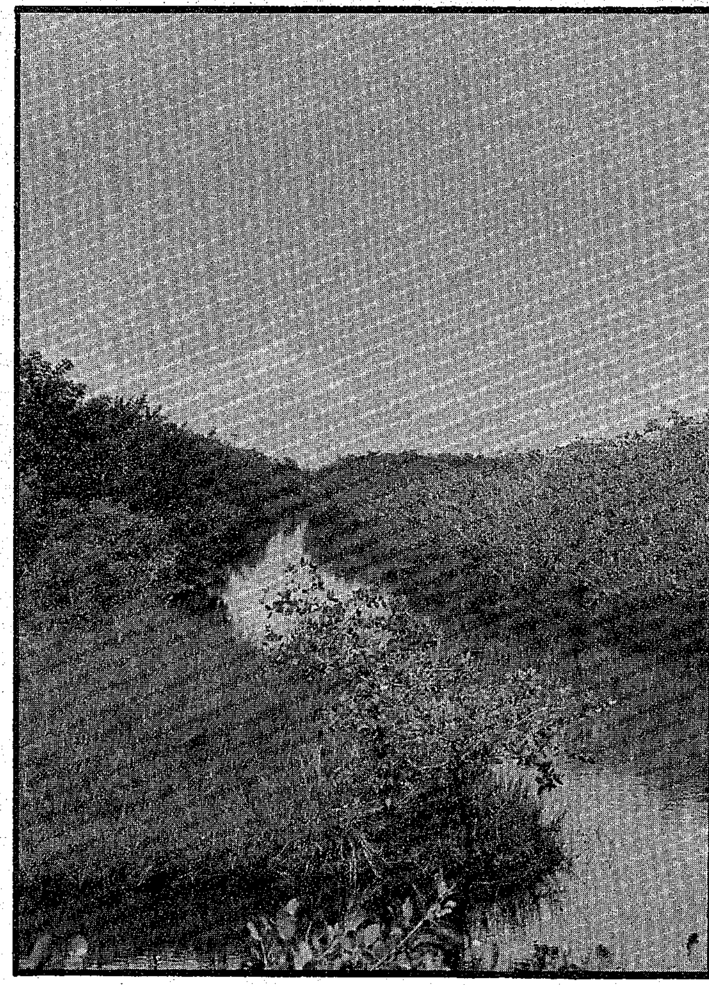
The combination dike-and-road at the wildlife refuge (white strip in photo) has cut off water circulation and thus reduced certain habitat values.

Figure 56. (far right)

Vegetation on the mainland fringe (left) is more vigorous than vegetation on the mangrove islands immersed in the impounded water of the wildlife refuge (right).

The Wildlife Refuge: The dike at the wildlife refuge prevents effective tidal penetration into mangrove swamps and shallow bayous. (Figure 55) Seasonal rains are insufficient to maintain an alternative freshwater habitat, so the area seems to exist as a highly unstable, somewhat brackish habitat effectively isolated from the rest of the estuary.

Organic production in parts of the impoundment appears too high for the natural removal processes (mixing and flushing). For this reason, heavy organic buildup occurs, resulting in high BOD levels, methane production, and a dominance of blue-green algae. The construction of the scenic roadway across these already poorly flushed systems aggravated the problems. In fact, consultants have observed severe hypersalinity (salinity in excess of 50 percent) in early June. Mangroves within the confines of the road system appear to be stressed.[65] (Figure 56)



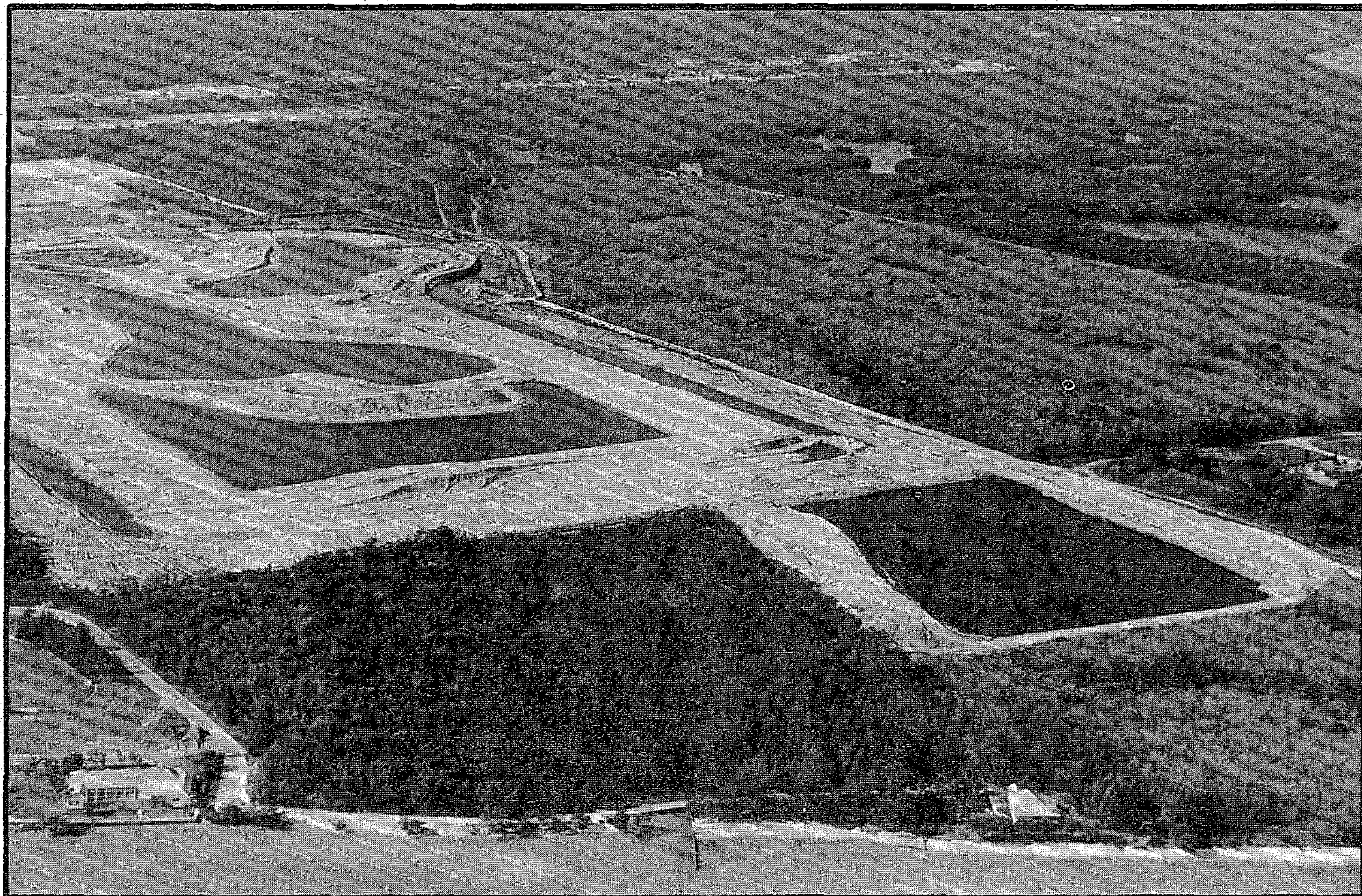


Figure 57.

Seventy acres of thriving mangroves were killed (gray area, upper right) after they were isolated from the estuary by a road and flooded when the adjacent excavation was dewatered (left).

As a result of low oxygen, variable salinity, and a stressed flora, the fauna also suffers. Only a few species of fishes and invertebrates can withstand low oxygen conditions. Therefore, species diversity is low, but the few successful species can exist in large numbers.

In certain areas, the soil salinities have become sufficiently high to cause the formation of salterns or "salinas" consisting of open sand areas with sparse, stunted black and white mangroves.

Infared and aerial photographs indicate that red and black mangroves have suffered stress reactions. Conservation Foundation consultants recommend careful examination of the mangrove communities within the artificial impoundment since they are evidently reacting adversely to an effect induced by the impoundment levees.

The Dixie Beach Boulevard Area: A tract of about 70 acres of tidal mangroves east of Dixie Beach Boulevard was recently killed when an adjacent area was dredged and filled.[66] (Figure 57) Excessive flooding with fresh water during construction caused heavy mortality of trees within the tract; the culvert beneath Dixie Beach Road was inadequate to release the increased water. Although larger culverts were installed early in 1974, and 40 acres replanted with mangrove seeds, most of the tract still is deprived of adequate tidal circulation. Its chances for recovery are unknown.

To the west of the boulevard, the mangrove community ranges from a tidal red mangrove at the bay edge to supratidal, high elevation, mixed mangrove community (black, red, and white mangroves). Mosquito ditches penetrate this community from the bay to the Sanibel-Captiva Road. The inland end of each ditch was largely stagnant at the time of the field survey. These stretches probably are not effective in controlling mosquitoes—cyprinid (mosquito predators) populations were very low in comparison to those existing in the more seaward portions of the ditches.

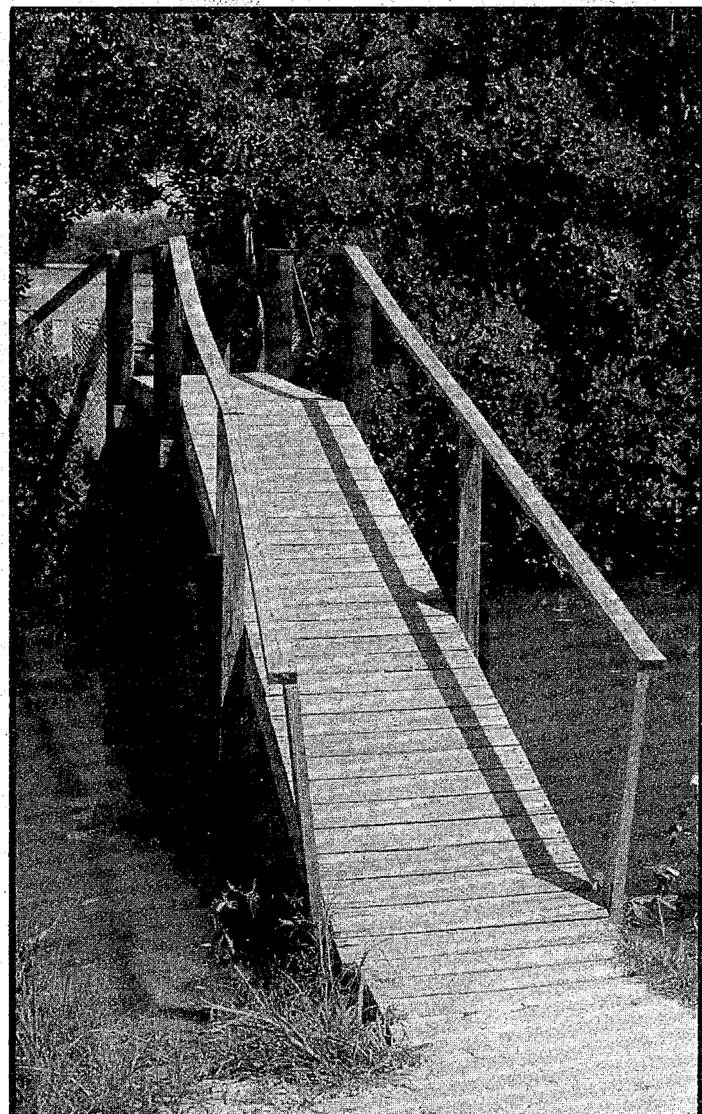


Figure 58.

Elevated catwalks such as this in the wildlife refuge are preferred because they do not block water flows.

Management Recommendations for Mangroves

The protection of mangrove forests should be an essential part of Sanibel's environmental program. As in the case of the interior wetlands, the protection of the functional integrity of mangrove wetlands precludes virtually any alteration. The same protection is therefore needed against excavation, filling, grading, draining, vegetation clearing, release of pollutants, solid roadways, and other blockages. It is particularly important that mangrove areas not be drained, by canals or otherwise.

The only appropriate structures in mangroves are the pile-supported recreational ones suggested for low-ridge-and-swale interior wetlands. (Figure 58)

Restoration of mangrove systems is required in several damaged areas. The large tract of damaged mangroves along Dixie Beach Road should be restored to full functioning condition by providing adequate water flow beneath the boulevard and such other actions as are required. Also, any other areas that have been damaged by impoundment, drainage, or other actions should be restored by the most expeditious means possible.

CHAPTER 6

UPLANDS

Identification of Uplands

The Gulf Beach Ridge Zone is the major ridge immediately behind the beach. It is stabilized by dense vegetation.

The Mid-island Ridges Zone comprises the major ridges along the central axis of the island, and includes the highest elevations. In most areas, this zone divides the bay-mangrove watershed from the interior wetlands watershed.

Surface Hydrology and Soils: The upland areas are inundated only during major hurricanes, and are the driest part of the island. There is no naturally existing surface water here. All rain immediately percolates into the ground because of the high soil permeability and relatively high elevation.

Soils of the uplands are immature, thin organics of the Canaveral series. In some places they have high salinity because of salt spray and hurricane overtopping.

Uplands Vegetation: Sanibel's uplands vegetation is largely secondary—or seriously impacted by exotic plants. In places it is desertlike in appearance because of its adaptations to drought. About 1900, the island vegetation probably resembled an extensive prairie, much like northwest Cape Sable appears today (an extensive graminoid cover with lines of cabbage palm on the slight ridges).[67]

The ragweed-castor bean association is a group of herbaceous annuals which readily invades newly cleared areas. Alexander describes 18 "recovery" plants associated with this group.[68]

Cabbage palm is the most ubiquitous plant on the island. It appears as stands—lines of trees along ridges—and is especially common in transition areas between the upland ridges and the interior wetlands.

The West Indian tropical hardwood flora—which probably is scarce historically—occurs only on Wulfert Point and the narrow upland ridges.

The Australian pine-cajeput-Brazilian pepper category represents the introduced species of the island. They rarely occur together; each tends to form pure stands and eventually outcompetes native species.

The island's slash pine probably represents a relic community. Its natural habitat is shared with the saw palmetto.

More information on current vegetation of the island is presented in the section of this chapter dealing with the condition of the uplands.

Wildlife of the Uplands: Although the uplands cannot compete with other habitats on Sanibel for size and variety of birds, 11 species do nest there, including: pileated woodpecker, smooth-billed ani, red-bellied woodpecker, great crested flycatcher, purple martin, fish crow, starling, white-eyed vireo, prairie warbler, house sparrow, and cardinal.[69]

Upland reptiles and amphibians include: Florida box turtle, gopher tortoise, common iguana, green anole, Key West anole, southeast five-lined skink, ground skink, six-lined racerunner, eastern glass lizard, Florida brown snake, southern ribbon snake, southern ringneck snake, southern black racer, eastern coachwhip snake, indigo snake, yellow rat snake, coral snake, eastern diamondback rattlesnake, greenhouse frog, southern road, green tree frog, squirrel tree frog, and Cuban tree frog.[70]

The mammals of Sanibel's uplands often appear in other ecological zones as well. Three rare or endangered mammal species are found on the island: the Florida bobcat, the cotton rat, and the Florida panther. Both the bobcat and the panther are secretive and seen infrequently. The raccoon, marsh rabbit, feral domestic dog, roof rat, and house mouse are common. One gray squirrel, a few gray foxes, mink, and round tail muskrats have also been sighted on the island. The mammals found on Sanibel include: opossum, armadillo, marsh rabbit, house mouse, roof rat, Sanibel rice rat, cotton rat, raccoon, otter, Florida panther, Florida bobcat, feral domestic cat, and domestic dog.[71]

Condition of Uplands

The major ecological alterations to Sanibel's uplands areas appear to have been caused by farming, invasions of exotic plants, and excavation of artificial lakes and waterways.

Farming: Farming has caused widespread changes in basic vegetation patterns. For example, a cabbage palm proliferation followed the abandonment of farming. Apparently, this had been a common species on the island but it did not spread until the late 1920's when it exploited the land lying fallow after the 1926 hurricane. In 1955, according to Cooley, cabbage palm was the most common plant on the island—and it continued to be so two decades later.

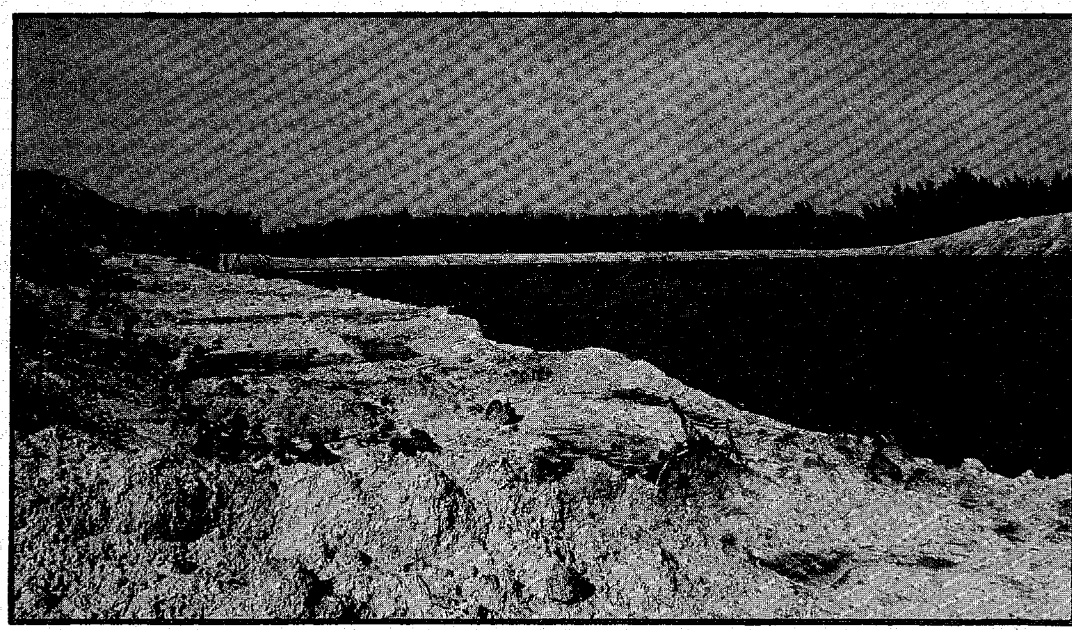
Farming practices in the past eliminated much of the native vegetation, leaving the uplands vulnerable to alteration by an invasion of exotics. A new dominance of Australian pine and Brazilian pepper has changed historic wildlife patterns and lowered the productivity of the soils. Unaltered upland habitat is now in short supply.

Exotic Plant Invasions: Australian pine and Brazilian pepper represent the worst of the island's vegetation problems. Each almost always becomes the dominant plant after it occupies an area. Alexander says the two plants "have proved to be disastrous to the natural ecosystem."[72] The Conservation Foundation's consultants believe that these species should be removed where they occur, and should not be planted in the future. Australian pine can be controlled by fire and poison. Stump sprouting is common, so cutting in itself is not a permanent control. Two species should be considered for replacement: slash pine and southern red cedar.

The cajeput (or punk tree) is another exotic capable of dominating a natural habitat. Seed supply is always available on the trees. Should an area be disturbed and seeds

Figure 59.

The excavation of artificial lakes on Sanibel has caused many ecological problems, including loss of wildlife and degraded water quality.



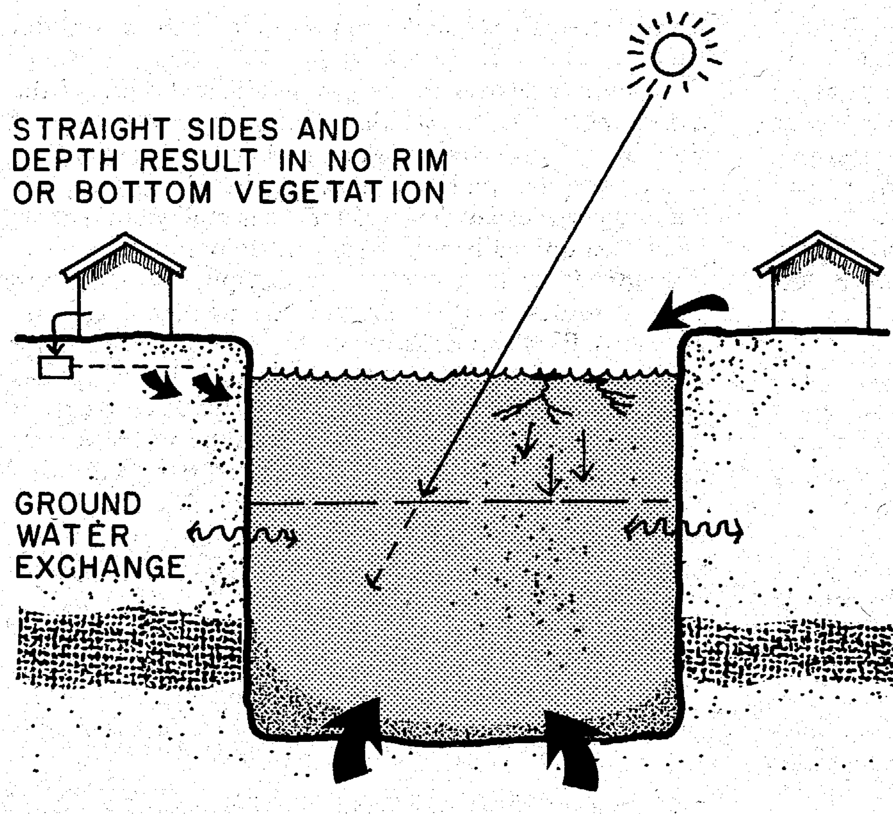


Figure 60.

Improperly designed man-made lakes can become grossly polluted in only a few years.

released at a time of favorable soil moisture, a closed community of cajeput would develop. Cajeput is salt tolerant and can invade mangrove communities on the brackish water margins. Furthermore, it is not controllable by fire.

Artificial Lakes: Many artificial lakes, ponds, and other bodies of water have been excavated on Sanibel Island during the last 10 years. These excavations, known as "real estate lakes," were dug mostly to obtain fill material for surrounding land in order to meet housing regulations and obtain septic tank permits. These have caused a number of ecological problems. (Figure 59)

The lakes have exacerbated the salt-intrusion problem. In the island's undeveloped state, most of the salt water thrown up by storms would run off in a short time. But a hurricane surge will fill the man-made lakes, and salt water will intrude deeply into the groundwater system. Because these lakes typically have no provision for drainage, the salt water will remain for long periods. (Figure 60)

The excavations have had pronounced effects on the water-table aquifer both in the construction phase and after completion. Several of the lakes and canals were dug too deeply, removing all or part of the confining clay and marl stratum. This permits upward leakage of high chloride water from the shallow artesian aquifer into the water-table aquifer. During excavation of several ponds, a dewatering process was used, which caused wide dispersion of high chloride water from the lower part of the water-table aquifer. The pumping also could have caused upward leakage of saline water from the shallow artesian aquifer.

In addition to aggravating the salt problem, the man-made lakes cause another serious form of delayed pollution. Loading of the lakes in the interior wetlands with

sewage wastes, fertilizer-pesticide runoff, and sediments will lead to gross pollution in the future. Lake pollution is a delayed reaction—its true dimensions do not appear for several years. At present, the majority of lakes on the island have not yet become rancid, but some are polluted and others will become so in the future.

All the lakes now provide a free water surface which facilitates evaporation and causes the water table in adjacent areas to recede at more rapid rates than in the past.

In summary, the lakes now act as accumulation basins

Figure 61.

All waterways on Sanibel should be protected.

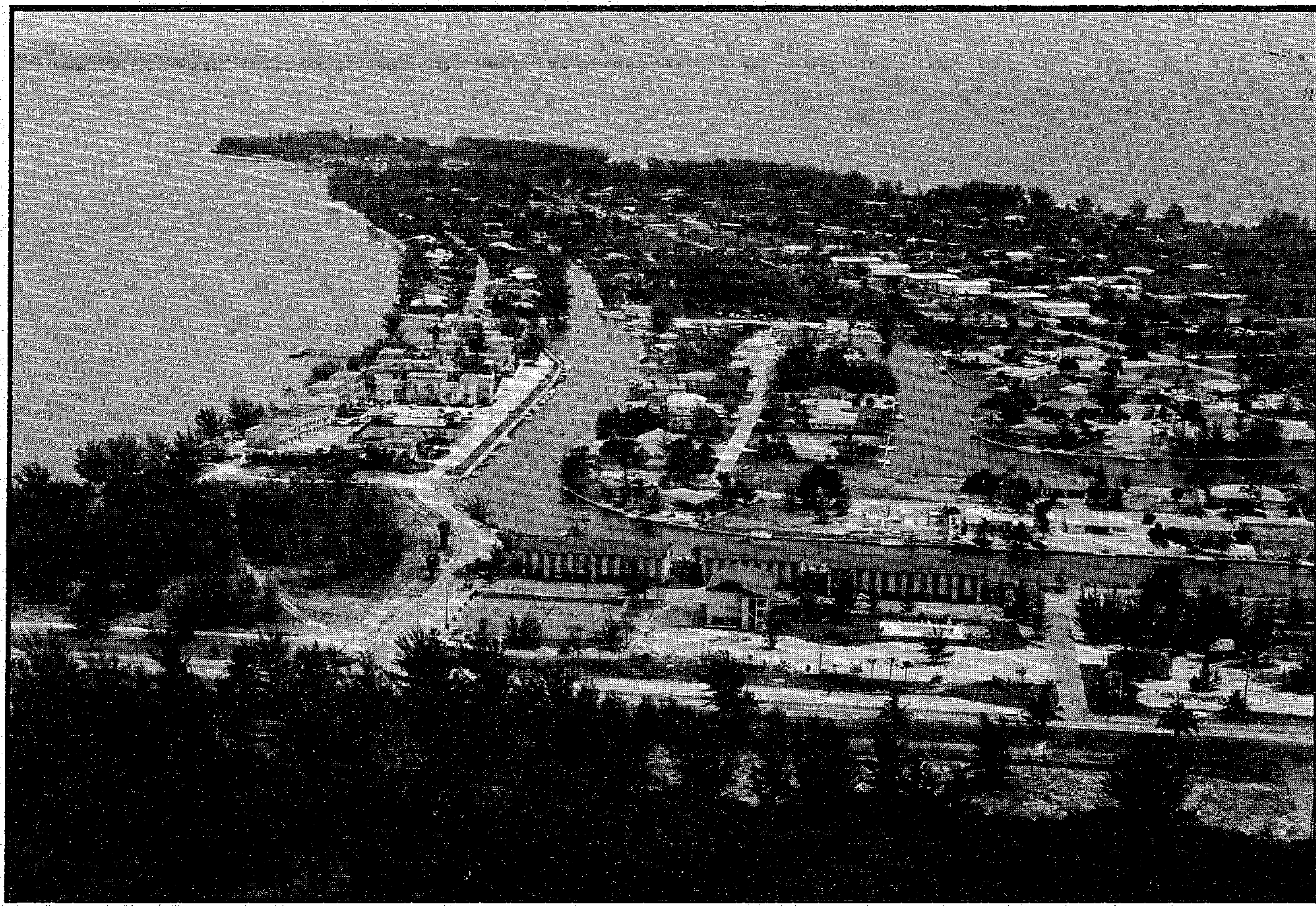


Figure 62.

Internal canals connected to the sea can damage the island ecosystem by draining the land and causing intrusion of salt water.

for highly saline water, septic waste, and organic detritus. Depressed oxygen conditions prevail in many of the excavations and lakes.[73]

Management Recommendations for Uplands

While the focus of attention should be directed toward the conservation of the areas of high ecological sensitivity previously discussed, habitation of the ridges and other upland areas of Sanibel must also be closely controlled. The principal need is to ensure that development of uplands is compatible with water quality and water-level protection.

Site Preparation: To protect water quality and water resources, development sites should be prepared with special care. The following measures were recommended by The Conservation Foundation:

1) No alteration of existing natural waterways or tributaries should be permitted; water should not be pumped for dewatering of excavations or related purposes. (Figure 61)

2) Artificial drainage ways should be confined within the boundaries of each separate project area and should not drain into wetlands or surface waters.

3) There should be no excavation or underground installations which penetrate the clay seal (or aquaclude) and cause salt water to leak upward.

4) Disturbance of natural vegetation should be limited to the minimum necessary for each building site and for basic landscaping.

5) No canals should be constructed which connect to salt waters. (Figure 62)

Artificial Lakes: To maintain ecologic balance in real estate lakes, great care must be taken both in excavation and in filling. Water quality degradation in these man-made lakes increases over time, often accelerating as projects are built. The lakes gradually accumulate pollutants and sediments and can become grossly polluted if not properly designed and maintained. The Conservation Foundation recommended the following measures:

1) Lakes should be deep enough to provide at least four feet of water at the lowest water stage to ensure that rooted aquatics such as cattails do not take over. (Figure 63)

2) Lakes should be shallow enough to permit the maintenance of acceptable water quality through wind turnover—generally no deeper than seven or eight feet below seasonal high water (at greater depths, wind turnover is unlikely to prevent an accumulation of polluting substances in the deeper water at the bottom).

3) Lakes should also be wide enough to ensure mainte-

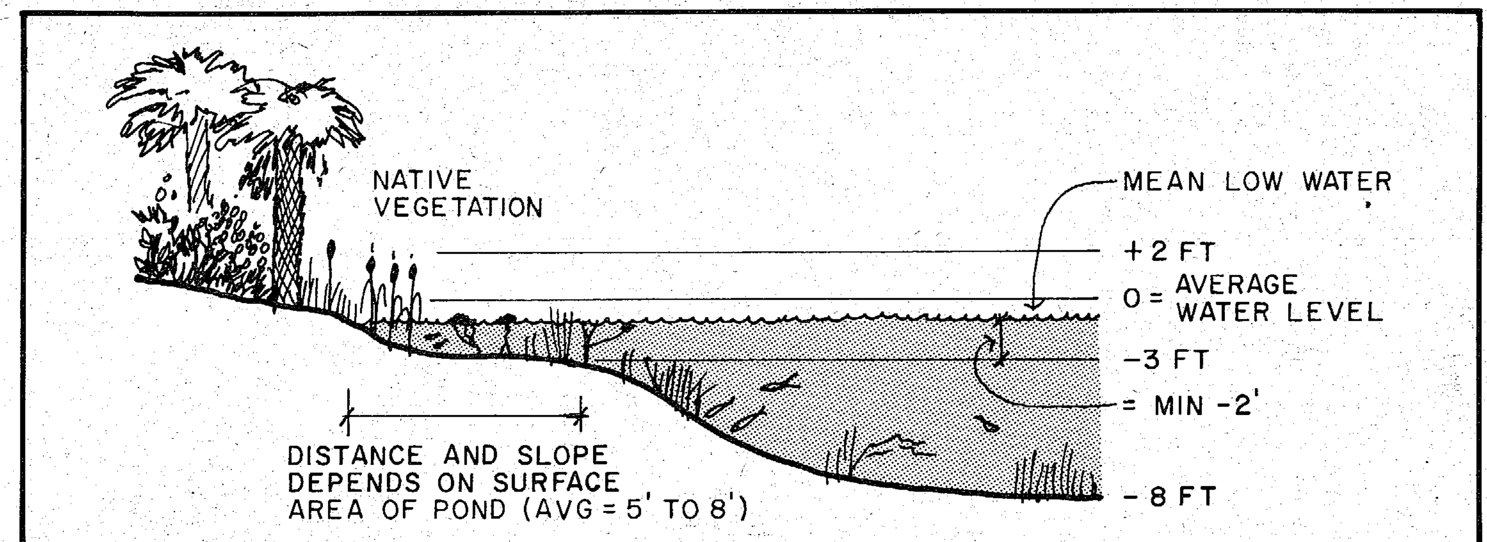


Figure 63.

Recommended design features for artificial lakes.

nance of water quality through wind turnover (a seven-foot-deep lake should have dimensions of more than 500 feet to provide for turnover).

4) The edge configuration of lakes should provide for acceptable wildlife habitat without an overgrowth of cattails. Also, a naturally vegetated and undeveloped wide buffer should be provided around the lakes of a width sufficient to control runoff pollution and provide wildlife habitat.

5) Provision should be made for routine weed control and maintenance dredging to remove accumulated sediments and pollutants from all real estate lakes.

CHAPTER 7

SPECIAL ZONES

Identification of Special Zones

Four special ecological subsystems were identified for city management purposes:

1) Blind Pass area (geologically unstable ridges at west end of island, interspersed with lagoons with high susceptibility to pollution);

2) Filled land (areas where ecology has been adversely altered by artificial fill);

3) Preservation spot zones (confined areas that serve unique and valuable ecological purposes); and

4) Refuge areas. Although the wildlife refuge is not under city jurisdiction, it was believed desirable for purposes of coordination with the city to classify the refuge by the following subsystems: impounded mangrove; main mangrove forest; Tarpon Bay; Ladyfinger Lake; interior wetlands (including Bailey Tract); and Lighthouse Point.

Blind Pass Area: At the western end of Sanibel is the ecologically distinct Blind Pass area. Most of this land has been created in the past 200 years, and it has undergone many changes. (Figures 64, 65, 66) Several brackish, fingerlike bayous extend through this area.

The waters of this area—Clam Bayou, Old Blind Pass, and Blind Pass—exchange with waters from the Gulf of Mexico through an inlet at the southwestern corner of Sanibel Island. The shallow inlet is guarded by a sand bar, except for a narrow channel near the shore of Sanibel. The sand bar at the inlet indicates that the magnitude of tidal flushing is not great. Wind-induced flushing is reduced by the sinuous nature of the bayous and blockage of wind by Australian pines and mangroves. Density differences caused by evaporation and rainfall produce some flushing, but the sand bar hinders this.

If, as suspected, flushing is minimal, then pollutants from adjacent human activities should be prevented from entering the system. Consideration should also be given to increasing flushing. The inlet could be dredged to improve circulation, and the old cut to the east could be reopened to improve flushing. These "improvements" would be made in opposition to natural trends and would require maintenance dredging.

The Conservation Foundation made the following recommendations regarding the Blind Pass area:

1) Human occupancy of the area should be severely limited.

2) No runoff from any adjacent urban development projects should be discharged into the heads of Dinken Bayou or Old Blind Pass.

3) No sewage or septic tank effluents should be discharged or allowed to leach through the groundwater and reach the lagoons.

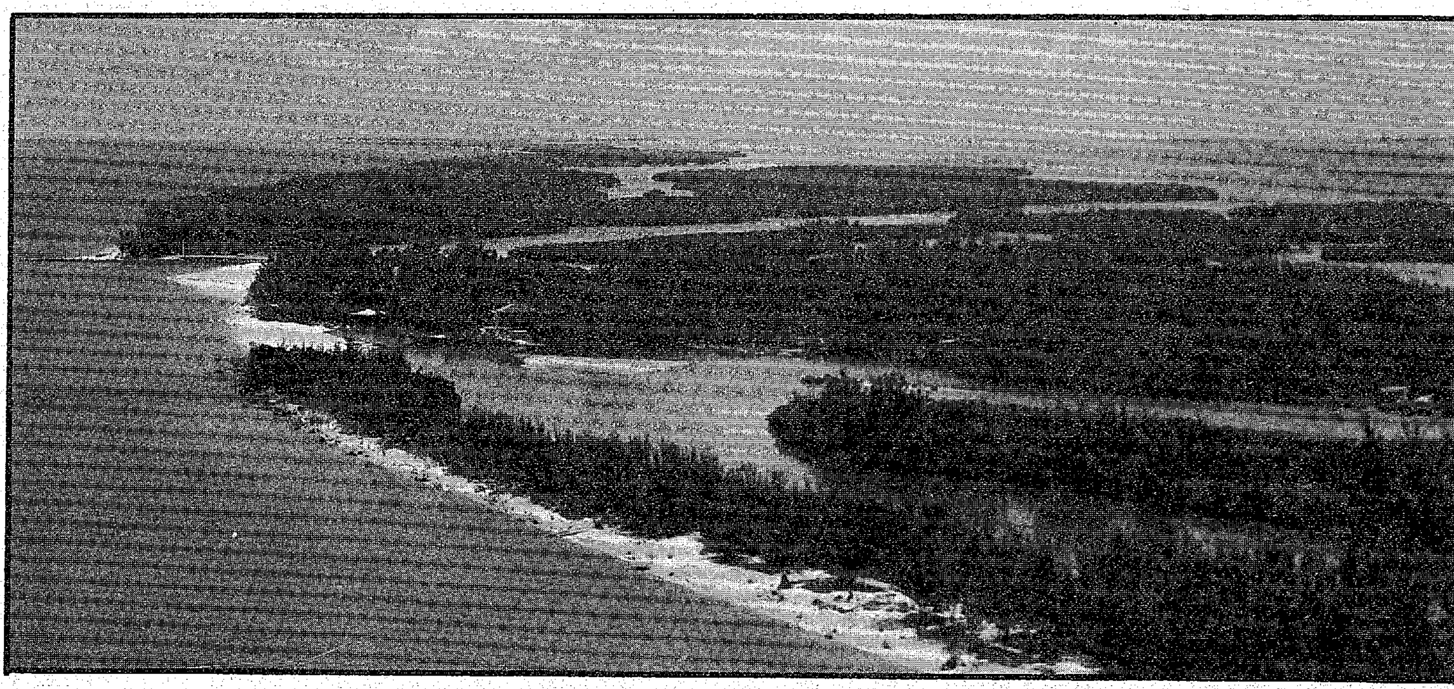
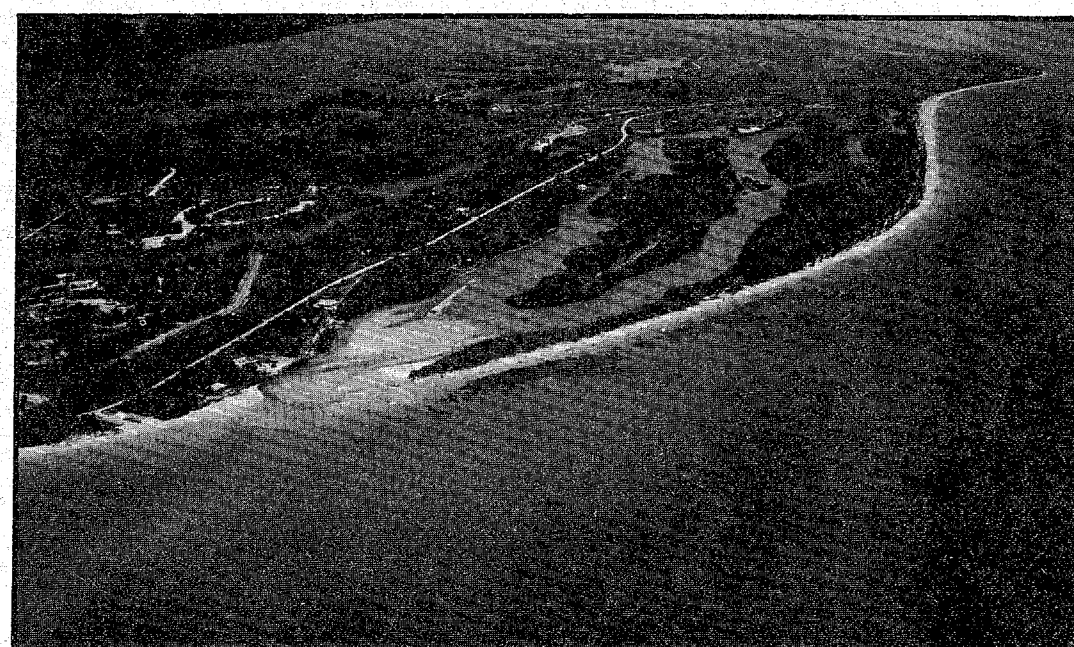


Figure 64.

The highly productive and geologically active Blind Pass area is extremely vulnerable and presents special management problems.

Figure 65.

The bayous in the vicinity of Blind Pass are now closed off from tidal circulation and flushing; effective pollutant removal and dilution have therefore been stopped.



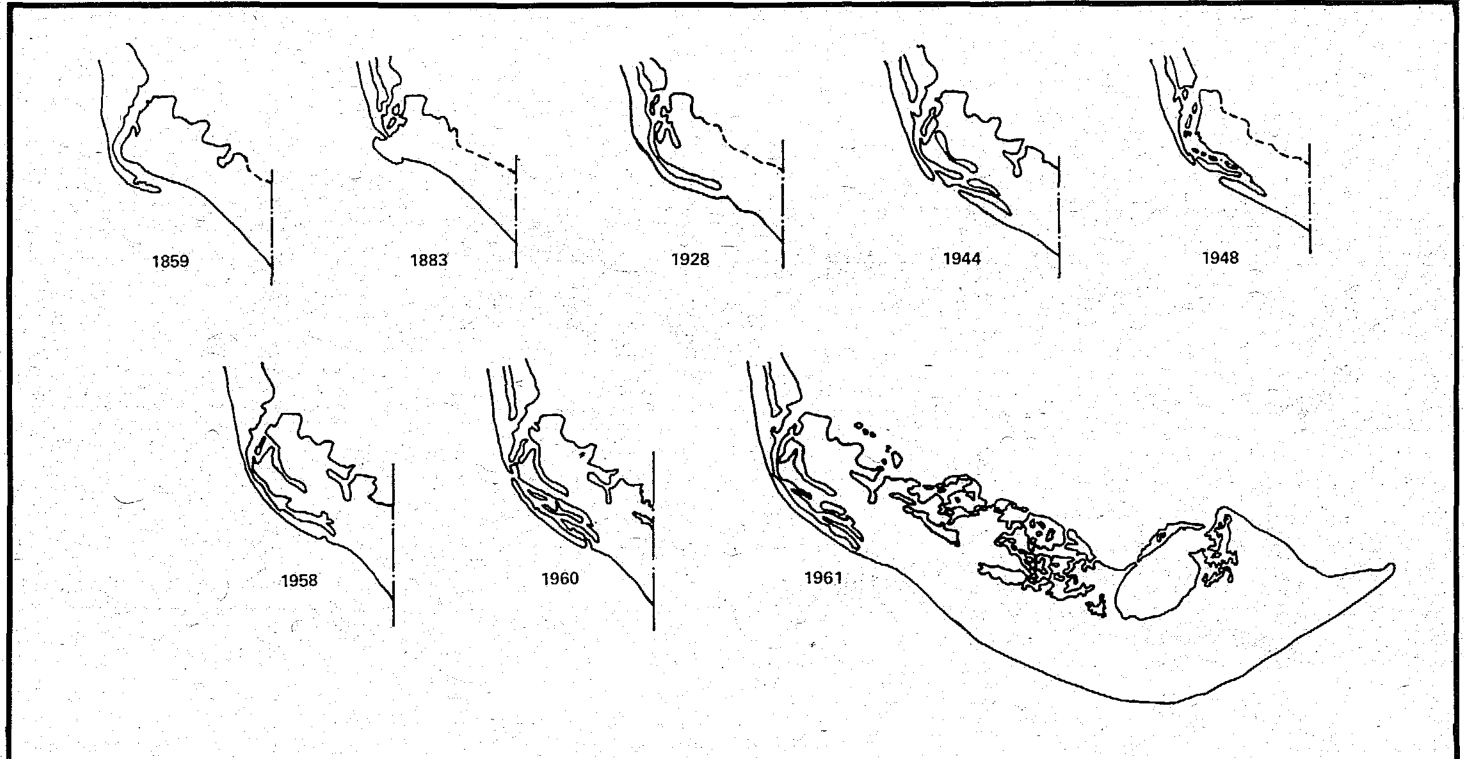
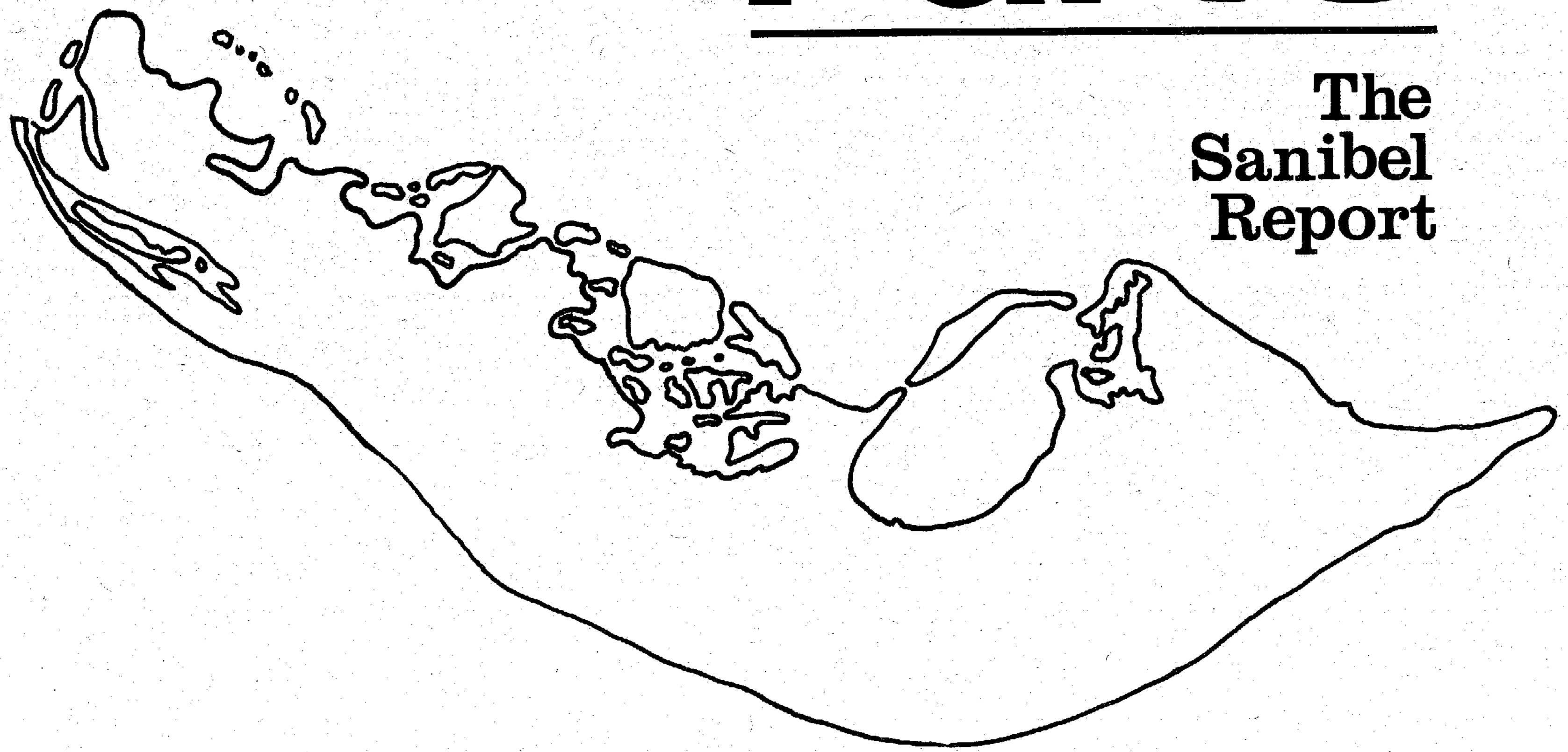


Figure 66.

Recent ecologic history of Blind Pass area, 1859-1961. (Source: Duane Hall and Assoc., 1975.)

Part 3

The Sanibel Report



Part III describes the planning process and the Sanibel Plan, and also how the natural systems study by The Conservation Foundation was useful to the planners.

The Planning Commission began work on the comprehensive plan for Sanibel shortly after the new city government took office in December 1974. By March 1975, the commission had prepared specifications for the planning study and in May the data gathering began. Preliminary reports by Wallace, McHarg, Roberts and Todd (WMRT) and The Conservation Foundation (CF) were delivered in July, August, and September. In December, the first draft of the Sanibel Plan was available for public review. During the next seven months, the plan and the regulations were modified according to public reviews. In July 1976, the plan received final approval, and the moratorium on new building permits ended.

Part III consists of two chapters: the first reports on the planning process; the second presents an abridged version of the final plan. Chapter 8, "Formulating the Plan," was prepared jointly by CF and WMRT—William H. Roberts, partner of WMRT in charge of their studies, is the principal author. The chapter focuses generally on interactions of those involved in the planning process and specifically on the roles of WMRT, as planning consultants to the city, and CF, as ecological analysts sponsored by the Sanibel-Captiva Conservation Foundation (SCCF).

Chapter 9, "The Plan," is a photo-reproduced abridgment of the official Sanibel Plan (the formal title is "Comprehensive Land Use Plan, City of Sanibel, Lee County, Florida"). The plan's table of contents is also included and indicates the full scope of the plan. The material in Chapter 9 is reproduced directly from the plan and is intended to emphasize natural systems, the subject of this report.

A limited number of copies of the complete plan are available from the Planning Commission, City of Sanibel, Florida 33957, for $15.00 each.

CHAPTER 8

FORMULATING THE PLAN

The Sanibel Plan resulted from a total community effort which involved extensive interactions among citizens, government officials, and consultants. The role of the Sanibel Planning Commission was to gather and analyze data, to determine community needs, and finally to present a comprehensive plan to the mayor and City Council for adoption. Plan formulation was a dynamic process wherein the public, their representatives, and the consultants measured impacts, considered alternatives, and refined the plan to its final form. (Tables 9, 10)

The principal consultant to the city was the planning firm of Wallace, McHarg, Roberts, and Todd. WMRT engaged Fred Bosselman of Ross, Hardies, O'Keefe, Babcock, and Parsons, as legal consultant; Johnson Engineers, for utilities; and J.H.K. Co. for traffic studies. The Conservation Foundation in cooperation with the Sanibel-Captiva Conservation Foundation privately conducted a thorough ecologic study of the island. This was a unique and fortunate situation because in most cases the planning consultant must undertake such environmental studies entirely within his own contract. The CF study provided WMRT with more complete documentation of the island environments than would usually be available in planning programs of this type.

In June 1975, WMRT began developing base maps and socioeconomic data pertaining to historic and projected urbanization of the island, and at about the same time the CF team of 16 scientists began field studies. It was agreed that WMRT would assist and supplement CF's work by giving spatial definition to various conditions found in the field studies; for example, as the CF team developed working papers WMRT began interpreting aerial photographs to show distribution of plant types, and produced a vegetation map of the entire island. The best topographic information available was from a USGS survey that indicated contours at five-foot intervals. WMRT reproduced this at the same scale (1:1000) as the vegetation map and examined the correlation between vegetation and topography. Similar maps and testing procedures included surface waters, groundwaters, and historic geology. In each case the planners and their natural scientists asked the CF team to verify information based on their field work so that the base data remained consistent.

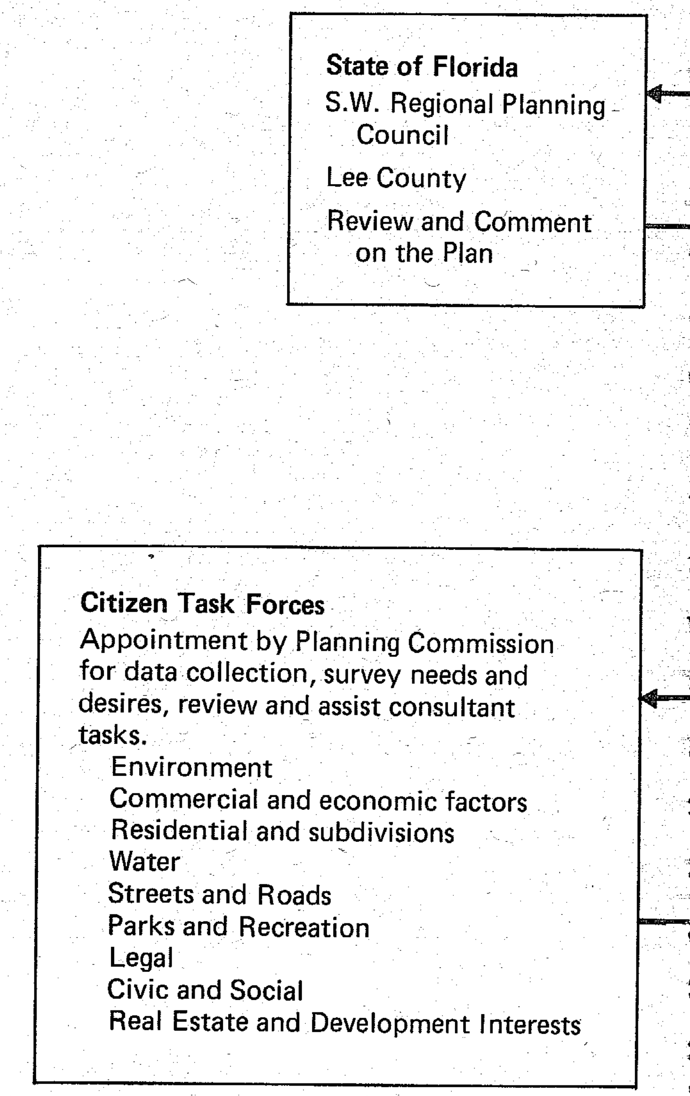
WMRT proposed that the island be described according to ecological zones. These zones were identified by CF as distinct regions of the island having particular ecological conditions and functioning systems.

CF scientists first suggested distinct habitats be delineated, but this was considered too specifically related to wildlife. The CF team evaluated WMRT maps and zone descriptions to ensure that the data had been interpreted correctly, and recommended minor modifications.

Progress reports, working papers, and maps showing the results were presented at public meetings of the Sanibel Planning Commission and made available for public inspection. The next step was to determine the relevance of this data in preparing a comprehensive plan for Sanibel's future. Descriptive data on roads, utilities, land uses, population, and other socioeconomic conditions, along with environmental factors, were discussed by the commission, members of special task forces, and residents and property owners.

When the island's present conditions and capacities were determined, it was possible to make projections of urbanization trends and evaluate the city's capacity to accommodate and service further growth. The planners projected alternative dimensions of future urban growth on the island and measured the commensurate demand for land and public services. Previous zoning for Sanibel by Lee County would have allowed up to a total of 30,000 dwelling units on Sanibel. It was clear to everyone that this level of development not only would totally obliterate the natural environment but also could not be serviced by safe streets, adequate water, or sewage disposal facilities. Also, Sanibel's economic base as a resort offering unspoiled beaches, a wildlife refuge, and the quiet ambience of a small village would be lost. Furthermore, the health, safety, and welfare of the residents would be in serious jeopardy. The planners discovered critical benchmarks of urbanization and population growth that might be accommodated—but if these levels were surpassed, economic sacrifices and other compromises would be necessary. One such constraint involved the limits of available technology and land area for disposal of treated effluent. Another was the capacity of the causeway to accommodate evacuation of residents to the mainland in the event of a hurricane. Also, the quantity and quality of potable water from the Lower Hawthorn aquifer was uncertain, and the capacity of the island road system for substantially greater traffic volumes was limited.

WMRT presented options to the Planning Commission that allowed the city to consider alternative levels of



THE STRUCTURE FOR PLANNING

State of Florida
Local Government Comprehensive Planning
Act. 1975-CH 75:257

Sanibel City Council
Mayor, Porter J. Goss
Zelda P. Butler, Vernon G. MacKenzie,
Charles R. LeBuff, Jr., Francis P. Bailey, Jr.
Responsible for adoption of a Comprehensive
Plan as a City Ordinance

Sanibel Planning Commission
Chairman, C. Duane White
Ann Winterbotham, Anina Hills, Lee Roy Friday,
Don Marshall, Joseph R. McMurty, George Tenney,
Emily Underhill; Planning Director: Sam Shannon
Responsible for preparation of Comprehensive Plan
for consideration by City Council

Planning Consultant: WMRT
Planning: Wallace, McHarg, Roberts and Todd
Partner-in-Charge: William H. Roberts
Jonathan Sutton, Anne W. Spirn
Legal: Ross Hardies O'Keefe Babcock and Parsons
Fred P. Bosselman, Charles L. Siemon
Economics: Dr. J.C. Nicholas
Engineering: Johnson Engineering
Traffic: J.H.K.

STUDIES BY OTHER GROUPS

Sanibel Captiva Conservation Foundation
and The Conservation Foundation
"Natural Systems of Sanibel"
Director of Studies: J. Clark
Local liaison in Sanibel: R. Workman

Natural Science Consultants
M. Brown—Energetics
G. Campbell—Reptiles and Amphibians
T. Missimer, J. Hartwell, P. Rosendahl—
Hydrology
O. Hewitt—Avian Life
J. Morrill, W. Byle, Jr. —Marine Ecosystems
S. Riggs—Geology/Beach System
D. Tabb, M. Roessler, G. Beardsley, E. Heald—
Wetlands and Mangrove Communities
T. Alexander—Vegetation
A. Veri, L. Warner—Water Quality

Other Input
Island Water Association
Chamber of Commerce
Civic Groups

Table 9.

Comprehensive planning integrated diverse and extensive groups.

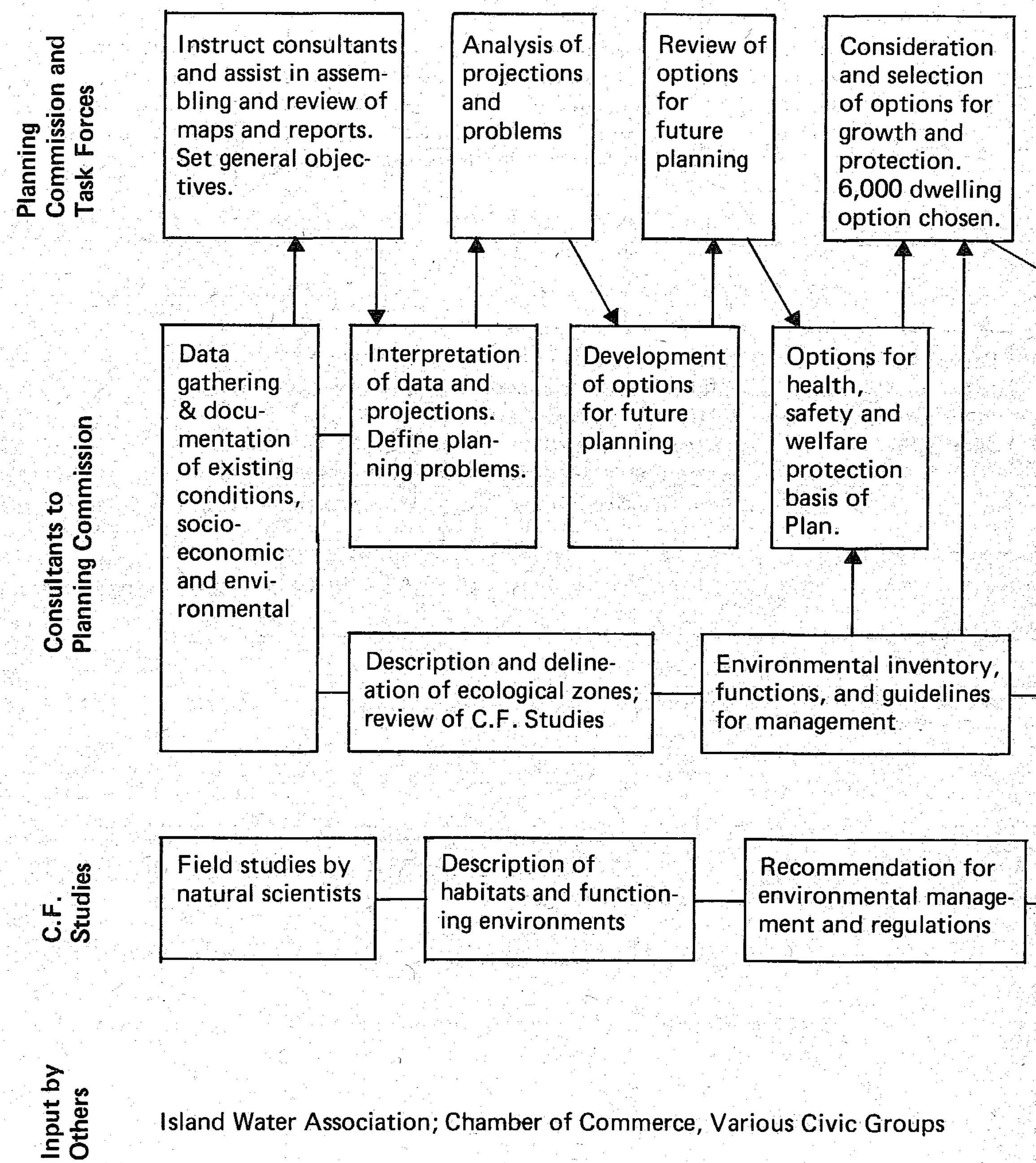
commitment of public funds to provide for alternative levels of future population. Options of 6,000, 8,000, 16,000, and 24,000 dwelling units were tested. On the basis of projected impacts, the Planning Commission recommended that a plan be developed based on 6,000 dwellings—2,000 more than the 4,000 units existing in 1975.

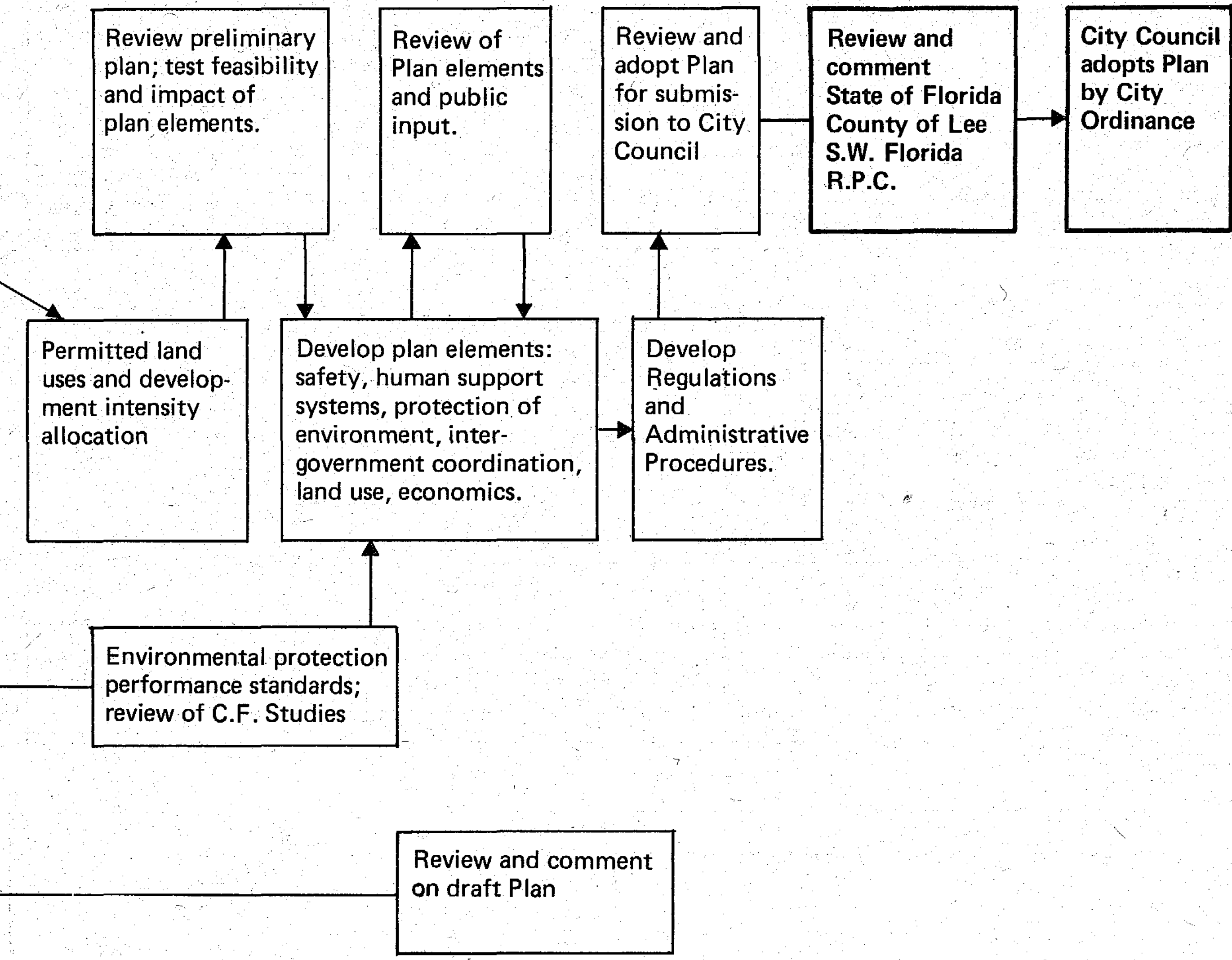
Once a tentative hypothesis had been developed regarding a total number of dwelling units to be accommodated during the period of the plan (Florida law requires revision every five years), the next task was to allocate those units among the various ecological zones. It was necessary to determine the tolerance of island environments to projected growth so that residents could appreciate the dimensions of prospective environmental impact before it occurred. To do this, WMRT planners and CF natural scientists first described the intrinsic function of each ecological zone in maintaining the natural systems within the respective zone, and then described the interrelated systems between zones. The WMRT chart of ecological functions is a major product of this task. (See page 22.)

WMRT then posed these questions to the natural scientists: What are the relative orders of importance of these environments given that some future growth on the island is desirable and inevitable? How much tolerance to change is there in each zone and what impact will it have? What guidelines are necessary to protect and rehabilitate Sanibel environments?

The planners developed a complex formula to distribute equitably the 2,000 additional units (Tables 11, 12). This formula took into account the relative suitability of each ecological zone to accommodate dwellings, and the proximity to human support systems such as existing sewer and water lines, fire stations, and egress routes in the event of evacuation. Also, the level of private investment in terms of development improvements was considered, as was the level of "build out" in established subdivisions where homes already had been built. The final product of this formula allocated densities to all land on Sanibel varying from one dwelling for each 33 acres to five dwellings per acre. Lower densities were allocated to environmentally fragile or hazardous lands and higher densities to areas where the environment could tolerate change and where support systems were available.

Having established the broad parameters of the plan,





THE PLANNING PROCESS — approximately one year duration

Table 10.

As this chart indicates, comprehensive planning was a complex process.

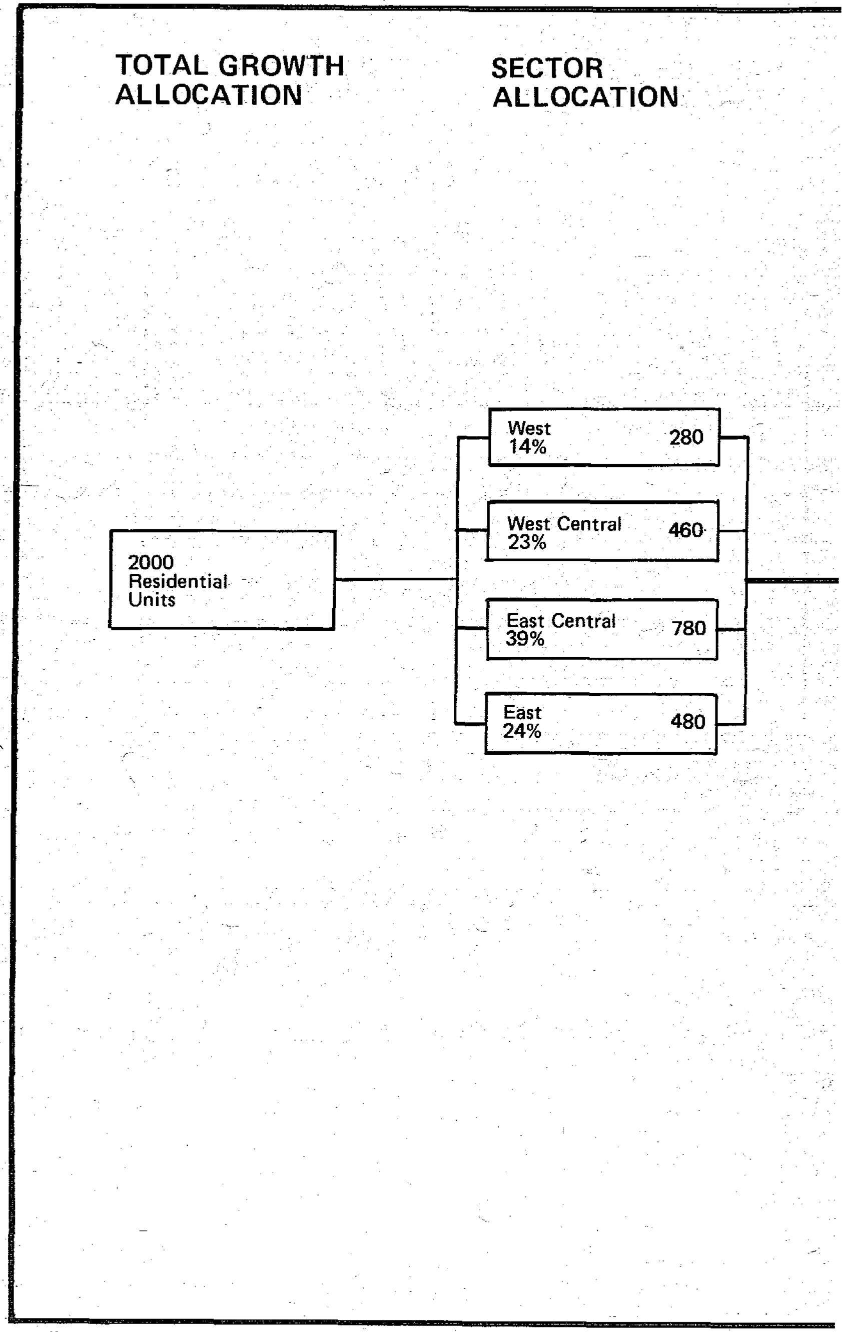
	West	West Central	East Central	East
1. Accessibility to Causeway	1	2	3	4
2. Distance from Existing Commercial	2	1	4	3
and Institutional Facilities	1	3	4	2
3. Availability of Fire Protection	1	3	4	2
4. Availability of Police Protection	1	3	4	2
5. Proximity to Water Service	1	3	4	2
6. Proximity to Sewer Service	1	2	4	3
7. Relative Amount of Developable Land	3	2	4	1
Totals	11	19	31	13
Sector Index	14	23	32	24
8. Dwelling Units	280	460	780	480

Table 11.

Planning sectors ranked by availability or proximity of services. (Source: Sanibel Plan).

the Planning Commission then held public hearings that specifically addressed problems of density. Individual lots, established subdivisions, partially completed condominium projects, and open parcels of land were reviewed to determine the feasibility of recommended densities and to make adjustments that seemed fair. This process, which took four months of arduous labor, including hundreds of hours of public hearings, eventually added 1,800 units to the plan's 6,000-unit ceiling. Few compromises to the intent of the plan were made but major accomplishments were achieved in terms of public support for a plan that would greatly reduce the pace of urbanization.

While this was occurring, Fred Bosselman and Charles Siemon of Ross, Hardies, O'Keefe, Babcock and Parsons drafted a set of comprehensive performance standards for the environmental protection of each ecological zone,



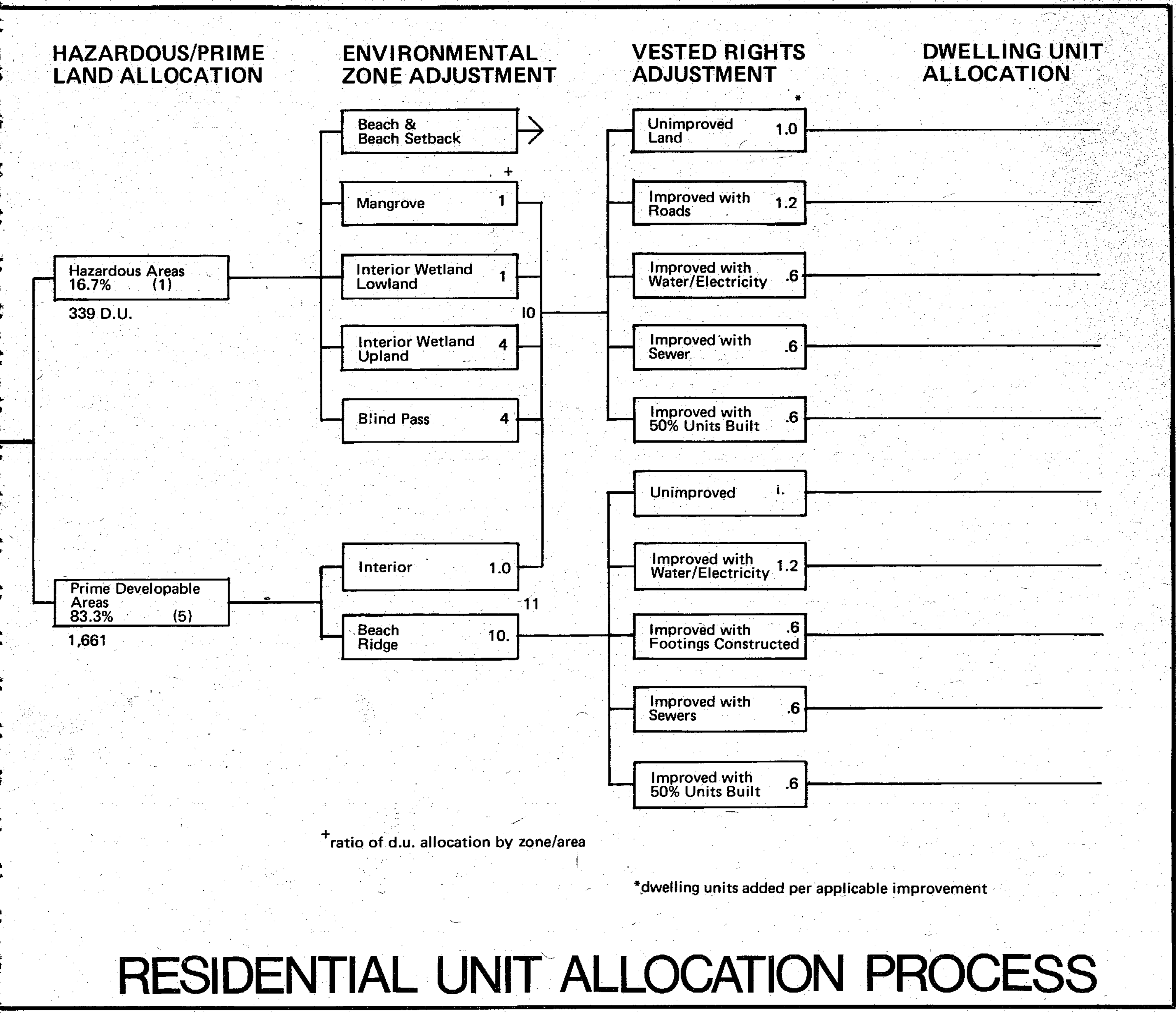


Table 12.

Steps in the residential unit allocation process developed for land-use management on Sanibel Island.

based on the recommendations of the Planning Commission and consultants, and incorporating many of the suggestions offered by CF in its interim report. These guidelines included setbacks from the beach and from water bodies, restrictions on clearance of vegetation and topographic disturbance for home building, and limits on the size of areas covered by impervious materials (in order to ensure groundwater recharge). Also, certain plants were termed undesirable and recommendations for their removal were made. Strict controls for on-site sewage disposal were proposed as supplementary to state and local health requirements.

Environmental factors influenced several elements of the plan but were focused primarily in the section called "Protection of Natural, Environmental, Economic, and Scenic Resources." Environmental factors also played a large part in the plan's development regulations, which included a description of permitted uses in each ecological zone and environmental performance standards for new construction in any zone.

The Planning Commission and its consultants went through a laborious process in considering ways to protect the environment while also accommodating the problems of property owners and builders. The commission held months of public meetings to hear the pros and cons of alternative means to achieve environmental conservation without unnecessary hardship. The social cost of depriving landowners of their expectation to build according to previous zoning was considered very seriously by the Planning Commission and consultants.

The final step in the planning process was to make the plan internally consistent so that all future land uses and improvements to human support systems were planned and could be financed. Administrative regulations were written to provide orderly consideration and issuance of permits, and to hear amendments to the plan. After considering five drafts for a comprehensive plan, the City Council obtained reviews by state, regional, and county governments. The council then held its own public hearings on the entire plan before adopting the final version in July 1976.

* * * *

Only a few months after the adoption of the Sanibel Plan the citizens of Sanibel had an opportunity to express their views at the polls. The terms of Mayor Porter Goss and Councilmen Charles LeBuff and Francis Bailey—all strong supporters of the plan—expired in November 1976. Councilman Vernon McKenzie, whose expertise as a former top official of the U.S. Public Health Service had been invaluable in the planning process, chose to resign for reasons of health. Thus four of the five council seats were up for election, with only Vice Mayor Zelda Butler (also a key plan proponent) guaranteed another two years in office.

For the three incumbents the verdict came early: No one challenged them. But for the vacancy caused by McKenzie's resignation, a contest was joined. Duane White, chairman of the Planning Commission, filed for the seat, as did Carol Quillinan, a representative of the Concerned Property Owners' Association, who had been highly critical of the plan. The public viewed the contest as, in effect, a referendum on the new plan.

On November 2, 1976, the voters gave Duane White more than 70 percent of the vote. The citizens who had worked hard on the planning process considered it a clear vote of confidence—a mandate for planning.

At Lee County elections on the same day, some of the strongest opponents of planning on the Lee County Commission were replaced by the voters. Moreover, the voters of Lee County supported, by more than 60 percent, an initiative petition, placed on the ballot through the efforts of a group of high school students, supporting a .5 mill tax levy to finance the purchase of Six-Mile Swamp, one of the major freshwater wetlands remaining in the county.

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CHAPTER 9

THE SANIBEL PLAN

† This symbol identifies deleted sections of The Sanibel Plan.

Many of the figures mentioned in the text do not appear in this abridgment.

Footnotes appear below the column of type in which the reference is contained.

How wonderful are Islands! Islands in space,
like this one I have come to,
ringed by miles of water. . . .
An island from the world and the world's life. . . .

Anne Morrow Lindbergh, **Gift From the Sea**

"WHEREAS, RESIDENTS OF SANIBEL ISLAND IN LEE COUNTY, FLORIDA, DESIRING TO HAVE THE RIGHTS OF SELF-DETERMINATION, TO THE FULLEST EXTENT ALLOWED BY LAW, IN THE PLANNING FOR THE ORDERLY FUTURE DEVELOPMENT OF AN ISLAND COMMUNITY KNOWN FAR AND WIDE FOR ITS UNIQUE ATMOSPHERE AND UNUSUAL NATURAL ENVIRONMENT, AND TO INSURE COMPLIANCE WITH SUCH PLANNING SO THAT THESE UNIQUE AND NATURAL CHARACTERISTICS OF THE ISLAND SHALL BE PRESERVED, DO SEEK THE BENEFITS CONFERRED ON MUNICIPAL CORPORATIONS BY THE CONSTITUTION AND LAWS OF THE STATE OF FLORIDA."

—from an Act relating to Lee County, establishing and organizing a municipality to be known and designated as the City of Sanibel and enacted by the Legislature of the State of Florida.

ARTICLE 1: PREAMBLE †
ARTICLE 2: ELEMENTS OF THE PLAN
Part 2.1: Safety

Section 2.1.1: Hurricanes

A. BACKGROUND DISCUSSION

Threat

The Island of Sanibel is subject to the periodic passage of hurricanes. A hurricane is a tropical cyclone with sustained winds of 74 mph or greater that is typically accompanied by heavy rain and thunderstorm activity. Hurricanes have struck the continental United States with winds as high as 250 mph. Hurricanes represent a wide variety of threats to various parts of the United States. In the interior reaches heavy rains and wind often produce floods and destructive tornadoes. Near the coast high winds propel loose objects through windows, doors and even walls, and lift off roofs. At the coast, the impact of hurricane winds and low barometric pressure on adjacent water bodies have reached nearly 25 feet and have inundated vast portions of low lying coastal land. These flood waters may spread inland at 30 mph and some locations may be inundated for 10 or more hours depending upon the speed of advance of the storm and the topography.

For Sanibel the storm tide represents a potentially devastating and dangerous event. The storm tide level predicted for Sanibel during the 100 year storm is 13.5 feet, a level that would inundate the entire island, and would be surmounted by large scouring and battering waves. The erosive power and battering impact of such a waterflow would seriously threaten the integrity of most structures on Sanibel and the life of any person stranded on the island. Of course, lesser storms can and will produce storm tides capable of flooding the entire island. The 1926 hurricane did just that, and forever changed the character of Sanibel's use by wiping out the Island's farming economy.

For planning purposes it is useful to consider the hurricane threat in terms of three general types of storm according to the direction of their approach. (See Figure 1.) The winds in a hurricane circulate counterclockwise around a center or eye. The most intense winds are those in the quadrant to the front right of the direction to which the storm is heading. The storm tide is the result of the continuous winds piling up water in front of the wind and the height depends upon the velocity of the wind and the distance that the wind is blowing over water.

A diagram outlining "State of Florida Regional Planning Councils," which originally appeared in Article 1 of the Sanibel Plan, appears as Fig. 1 in Chapter 1.

Each of these three types of storm has different ramifications in regard to warning time, evacuation procedure and potential damage.

1. Storm from the West. (Figure 1, Storm No. 1) A storm from the West is likely to be preceded by a flood tide. The timing and size of the tide will depend on the exact location of the storm and the phase of the tides. If the storm approaches from the west and makes landfall just north of Sanibel so that Sanibel is in the dangerous quadrant, the winds of the hurricane will build up water from over the entire distance of the storm's circumference and will produce extremely high tides. Depending on the severity of the storm's intensity, its size and speed of forward motion, flooding of parts of the evacuation route could occur up to 10 hours in advance of a westerly approaching storm.

2. Storm from the East. (Figure 1, Storm No. 2) The second general direction of approach is from across the mainland of Florida, the exiting storm. Historically a good number of storms have made landfall between Miami and West Palm Beach and have exited north of Sanibel. With such a storm evacuation of the island involves movement toward the storm, which would create severe traffic complications. Once the storm passes out into open water extreme tides may result. In one such storm Punta Rassa recorded flood tides of greater than 14 feet.

3. Storm from the South. (Figure 1, Storm No.3) The third general storm type is the southerly approaching storm. Donna in 1960 followed such an approach during its passage through the Fort Myers area. Because the storm winds will initially come from across the mainland, no substantial tide will be built up before the storm's arrival. If the westerly portion of the storm remains over water, however, a flood tide will succeed the eye. If the southerly approaching storm eye passes at or to the West of Sanibel, flood tides may precede the storm depending upon the distance

to the West the eye passes. In fact a passing storm 100 or more miles to sea might well flood the entire Island. In recent years two storms passing within 300 miles have produced flood tides which have almost broken over the Gulf Beach Ridge.

The actual direction of approach of a storm may be southeast, southwest or some other variable and as a result the actual storm effects on Sanibel for any particular storm will be widely variable. Nevertheless, it is possible to identify a range of impacts that can be expected. The passage of a hurricane within 50 or so miles of the Island would probably produce storm tides of 5-13+ feet msl with 5+ foot waves on top and sustained winds of 75-150 mph.

Refuge

Since Sanibel's ground elevation averages approximately 5 feet or less the Island is extremely vulnerable to flood tides of greater than 5 feet. It is therefore necessary that each person on the Island when a hurricane warning is received have an opportunity to reach safe refuge prior to the arrival of the effects of a hurricane.

Off-Island Refuge

The National Hurricane Center advises that evacuation from low lying coastal areas is necessary in order to protect human life from hurricane floods and winds. According to the National Hurricane Center, evacuation into elevated buildings located in a low lying coastal area with the physical and developmental characteristics of Sanibel, is not a satisfactory substitute for evacuation away from flood areas. Elevated refuges are not a substitute for evacuation from the Island, because the refuges would be isolated during and after the storm by high water, downed trees and hazardous conditions. The unavailability of medical services, delay in the restoration of essential services, outbreak of disease, and inadequacy of food and water supplies that could result from that isolation could subject refugees to an additional and unnecessary threat to their health and safety.

In recognition of the hurricane hazard on Sanibel and the inherent deficiencies of on-Island refuge, the City of Sanibel must plan for the evacuation off the Island of all of the persons who will be on the Island when a hurricane warning is issued. There is only one route for evacuation from Sanibel -- across the Causeway, Punta Rassa, and State Road 867.

In many places the evacuation route is a narrow two-lane road with little or no shoulders with elevations as low as 4.0 feet msl. This evacuation corridor is poorly suited for the vital task of evacuating the Sanibel populace. Even if the evacuation route proper were upgraded, feeder road flooding on Sanibel, tree and utility pole falls, discontinuous road design and storm conditions on the Island will inevitably diminish the load capacity of the evacuation route. In addition, portions of the same route will be used by as many as 102,000 mainland evacuees who live in other low lying coastal parts severely limiting the capacity of the route that will be available for Sanibel evacuees. If the mainland evacuees begin to clog the evacuation route, or if the route is blocked by a fallen tree or a camper blown over by the wind, the route will quickly back up leaving those still on the road at the mercy of incoming storm tides. If the route were blocked in Fort Myers so that the first evacuating car from Sanibel was halted, the line of traffic would back all the way up to Sanibel and some persons would be unable to reach the Causeway. Although two lanes are theoretically available, at least to Miner's intersection, it would be unwise to use both highway lanes for evacuation because emergency and control vehicles would not have access to the evacuation route in order to monitor and control the evacuation and keep the route clear. The initiation of wrong-way flow would be difficult and time consuming, and could well upset an otherwise controllable evacuation.

On-Island Refuge

There is currently very little on-Island hurricane refuge -- elevated to 13.5 feet msl on piling foundations, with pilings, walls and roofs capable of withstanding the 100 year storm and located away from the coastal high hazard area on Sanibel. Even though on-Island refuge is not a substitute for evacuation off the Island, such refuge must be available as an emergency measure for individuals trapped on the Island, especially in the event of a closing of the evacuation route by tree fall or other event. Additional on-Island refuge must be developed as a part of any future growth on the Island.

Warnings and Evacuation Time

The National Hurricane Center expects to be able to predict the arrival of a hurricane within 100 miles of Sanibel on the basis of information available 24 hours in advance of arrival of the eye of the storm. However, because it takes approximately 6 hours to code, process, and analyze the data and transmit the warning, ordinarily Sanibel can expect to receive a warning 12-18 hours in advance of arrival of the eye of the storm.

Nevertheless the entire warning period is not available for evacuation because there will be a cut-off time prior to the actual arrival of the storm. That cut-off time will occur because adequate time is no longer available for an evacuee to complete the evacuation trip to high ground before the effects of the storm strike the evacuation route. This may be because of preceding flood tides or because the evacuation routes are clogged with mainland evacuees.
Data gathered during hurricane approaches in the Gulf of Mexico indicates that storm conditions of high winds and tides sufficient to flood the Causeway,depending on the direction of approach of the storm and the storm's intensity,could reach the Island and the evacuation route between 4 to 6 hours or more before actual arrival of the hurricane eye. In addition, heavy rains may precede the eye of the storm by 6-12 hours and could flood parts of the evacuation route on the Island and on the mainland. High winds may also arrive 6 or more hours in advance of the eye of the storm felling trees and blocking the route. The ubiquitous Australian pine which lines the roads of Sanibel is particularly vulnerable to windthrow. The evacuation of the Island must be terminated far enough in advance of flood tides, the clogging of the route with mainland evacuees, and heavy winds and rains, to ensure that the last evacuee has more than adequate opportunity to reach safe refuge prior to the arrival of storm conditions. Since it is estimated that a minimum of one hour will be required for an evacuee to reach the relatively high ground portion of the evacuation route, the evacuation should be terminated at least one and one half hours before the predicted flooding of any portion of the evacuation route would make the route impassable for any of the reasons described above. The life of an evacuee trapped on the Causeway, Punta Rassa or other low lying part of the evacuation route during a hurricane would be in serious jeopardy.

Based on all available information, it can be anticipated that a maximum of 10 1/2 - 11 1/2 hours will be available for evacuation prior to the arrival of storm conditions. This period is comparable to the time frame which the National Hurricane Center recommends for planning purposes for South Florida coastal locations. THE VARIABLES THAT ARE INVOLVED IN A HURRICANE AND ITS EFFECT ON LAND COULD RESULT IN AS LITTLE AS SIX HOURS FOR EVACUATION.

Evacuation Capacity

The number of persons that can be safely evacuated from Sanibel therefore depends upon the amount of time available for evacuation, multiplied by the evacuation rate per hour. This figure compared to the population on the Island when a hurricane warning is issued, factored by the anticipated response rate, indicates what percentage of persons who want to evacuate can be successfully evacuated. It is incumbent upon the City to ensure that the percentage is as near 100% as is possible.

The many variables involved in a hurricane approach make it very difficult to estimate the number of persons that can be successfully evacuated from Sanibel in the face of an approaching hurricane. These variables include population, warning time, response time, road capacity, mode of evacuation, storm intensity and speed, direction of approach, recent hurricane history and time of year among others.

Evacuation Population

The number of persons to be evacuated is not easy to calculate. Sanibel is a seasonal resort with fluctuating populations. During the months of September and October the Sanibel population is at an off-season low according to water, sewer and traffic data. Even within that period the population varies especially near Labor Day when population spurts upward to perhaps 85% of peak, a weekend that has been subjected to extreme hurricanes several times since 1935. Nevertheless, dangerous hurricanes have appeared as early as June 9 and as late as December 2 within the last 50 years. Audrey (June 27, 1957), Alma (June 9, 1966) and Agnes (June 19, 1972) are a few of the hurricanes that have made landfall early in the "hurricane season." Audrey killed 600 persons and did $200,000,000 worth of damage.

In addition experience in developing resort communities in Florida indicates that seasonal fluctuations in population become less acute with the passage of time. The peak population which is on the Island during major summer holidays now, is increasingly likely to be on Island year-round.

Evacuation Population

Due to the inability to forecast with precision the numbers of persons likely to be on the Island in the event of a hurricane, it is only prudent to plan to evacuate the peak or holding capacity of the Island. This can be determined based upon the number of housing units, apartments, and resort accommodations existing on the Island.

Warning Time

The National Hurricane Center indicates that a hurricane warning upon which an evacuation order could be predicated will be issued between 12 and 18 hours before arrival of the storm center. However, flood tides, high winds and heavy rains may arrive between 4 and 12 hours prior to actual arrival of the eye of the storm.

Response Time

The amount of time necessary to warn and impel evacuees depends on a host of factors including recent storm history, prior personal experience, community planning and understanding of the magnitude of the threat. The National Hurricane Center estimates that 80% of the persons in hurricane hazardous areas in South Florida have never experienced a hurricane. When Donna passed through Fort Myers in 1960 there were only 300 persons living on Sanibel. Nevertheless, given the magnitude of the hurricane threat on the Island, the City must undertake planning and educational programs to ensure an efficient and timely response to an evacuation order.

Road Capacity and Mode of Evacuation

The primary mode of transportation during evacuation will be the private automobile. The availability, suitability, and carrying capacities of other modes such as boats, trucks, and buses and experience of other jurisdictions during hurricane evacuations suggest that only minimal numbers of persons will use these alternative modes. Consideration should be given however, to the use of school buses normally located on the Island to evacuate those persons without access to private automobiles.

With the exception of a small portion of U.S. 41, the evacuation routes both on the Island and on the mainland are all two-lane urban arterials or rural highways. "The capacity and service volumes of two-lane highways are expressed in total vehicles per hour, regardless of the distribution of traffic by direction."[1] The ideal uninterrupted flow capacities of a two-lane highway of good geometric design is 2000 vehicles per hour. This assumes 12 foot lanes, a lateral clearance of at least 6 feet from pavement edge to side obstruction, unrestricted sight distances of 1500 feet, level vertical alignment, and no trucks or large vehicles in the traffic flow.

While numerous isolated examples exist of measured peak hour volumes of 2000 to 2200 vehicles per hour, it must be recognized that these volumes are basically unstable and cannot usually be sustained for an extended period of time. Under such unstable flow, critical densities will be incurred which will cause stop-and-go conditions. Under stop-and-go conditions the maximum rate at which cars can move away from a stopped condition is 1500 passenger cars per lane per hour. Actual capacity will be less than this depending upon the amount of time the vehicles are stopped and the incidence of slower accelerating vehicles.

The conditions existing on many of the evacuation routes are substantially below typical design standards. For example, Periwinkle Way, the major arterial on the Island and primary evacuation route, has a pavement width of 18 feet or 9 feet per lane with lateral clearances of 4 feet. Assuming that 5% of the traffic will be trucks, these substandard factors will reduce the vehicle capacity of the arterial by 30%. Therefore, for uninterrupted flow conditions, the maximum capacity of the arterial would be 1400 vehicles per hour.

Another factor which must be considered is the effect of inclement weather on traffic flow. An evacuation being conducted during the time period of 6 to 18 hours before arrival of the full force of the hurricane may experience heavy rains and high winds. While extensive data on the effect of these road conditions or road capacity is lacking, numerous observations indicate that vehicle speed and density can be severely restricted. A 40% reduction in capacity is suggested as reasonable under severe weather conditions.

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[1]The Highway Capacity Manual, 1965 Edition HRB, Special Report, #87, Page 299.

The above traffic engineering factors suggest that a reasonable and prudent evacuation route capacity during hurricane conditions (6-18 hours prior to landfall or proximity of the hurricane center ,is approximately 700 to 800 vehicles per hour. Where evacuation route is subject to other specific hazards such as local flooding, road debris, or fallen trees such as is the case in Sanibel, the actual volume of vehicles moving out of the danger area could be considerably less. Unfortunately, there are no analytical techniques to estimate the reduced flow from these potential environmental interruptions.

Again, judgment and prudence suggests that a factor of 10% to 20% reduction in capacity would not be unreasonable to account for these interruptions.

Based on the above discussion, the City can reasonably expect to evacuate between 560 and 800 cars per hour.

The following is an example of the sequence of events preceding a hurricane strike:

HURRICANE APPROACH

HOURS BEFORE ARRIVAL OF EYE	
48-36	National Hurricane Center (NHC) issues hurricane watch for area including Sanibel.
47-25	Hurricane is monitored and predictions of movement are updated at 6 hour intervals. (2-3 hours if at all possible).
24	Data on hurricane collected by NHC for predicted landfall.
18-12	Hurricane warning is issued for area 150 miles either side of the predicted landfall. Warning received by Sanibel police chief. Decision is made to evacuate. Evacuation order is issued and emergency plan is instituted.
18-11	Hurricane warning and evacuation orders are delivered to each person on the Island by emergency teams. Evacuation begins as a small trickle of cars which steadily builds.
15-12	Evacuation reaches its peak.
12-8	Weather begins to seriously deteriorate, more persons decide to evacuate and the system begins to slow down from excessive loading.
12-6	Weather continues to intensify; evacuation efficiency reduced by tree falls and adverse driving conditions. Storm tides which will flood portions of the evacuation route are forecast for 8-5 hours prior to eye arrival. (Depending upon direction of approach) Evacuation across the Causeway is terminated at 6½ hours.
8-5	Storm tide floods low points on evacuation route -- route impassable.
4	Persons remaining on Island begin to move to on-Island refuge. Roadways with low elevation are flooding and tree falls continue as the weather continues to intensify.
5-3	Storm tides begin to flood the Island; roads below five feet become impassable because flooding inhibits clearing of fallen trees. Power is knocked out by winds and falling trees.
2	Weather continues to intensify. Wind blown debris becomes dangerous; on-Island refuge is accessible by foot only. Glass windows not covered would be broken by debris driven by high winds. Flood tides continue to rise.
1	Storm tide inundated; waves pass over major portion of the Island, winds continue to intensify. Persons who have not yet reached safe refuge are trapped in non-elevated structures.
	The Island is inundated; waves pass over major portion of the Island. Winds of 75-120 mph strike the Island. The most intense portion of the hurricane in the wall of the eye arrives.

Evacuation

Analysis of the evacuation capacity of the Island during the approach of a hurricane reveals that the City can anticipate that between 4,900 and 6,250 cars can be evacuated depending upon the severity of the storm if there are no major calamities which disrupt the evacuation route for more than one hour of the evacuation period.

B. THE PLAN FOR HURRICANE SAFETY

In response to this hurricane threat the City of Sanibel shall undertake to implement the following plans and policies including evacuation, population limitation, on-Island refuge, building codes and capital improvements:

Evacuation

1) The City shall provide each person on the Island when a hurricane warning is issued the opportunity to evacuate from the Island and to encourage persons to evacuate in a timely fashion.

   The City should continue to develop and improve the preliminary evacuation plan that was adopted on July 2, 1975.

2) The City should maintain a 24-hour communications link with emergency weather information sources.

3) The City should coordinate with Lee County and the City of Fort Myers in the development of an off-Island emergency plan for evacuation which will control traffic on State Road S867 and identify emergency shelters.

4) The City should upgrade the Island circulation system for improved traffic flow efficiency and roadways elevated above early storm flood levels and improve storm drainage.

5) Incoming traffic should be controlled at the Causeway toll booth as soon as a hurricane warning is issued which includes Sanibel.

6) The City should make provision for the rental or, if necessary, the purchase of three tow trucks for use in assisting disabled vehicles during an evacuation.

7) The City should develop an equipped emergency fallen tree and pole removing team for clearing fallen trees from the evacuation feeder routes.

8) The City should maximize warning capability including Island-wide sirens.

9) The City should develop a procedure by which the cut-off time for evacuation can be identified and enforced during the evacuation.

Population

1) The City should limit and manage growth so that the population on the Island when a hurricane warning is issued will not be substantially in excess of the evacuation and on-Island refuge capacity of the Island. Overloading the emergency system will reduce efficiency and deprive residents and visitors of a reasonable opportunity to reach safe refuge.

2) Future growth should be accompanied by and coordinated with, to the maximum extent practicable, improvements in the Island evacuation system and increases in the amount of on-Island refuge. It is only in anticipation of such improvements that the present population should be allowed to expand, because the evacuation capacity is already taxed during certain times of the hurricane season.

On-Island Refuge

It is the policy of the City to develop and improve off-Island evacuation as the principal refuge for its population. On-Island refuge is not a substitute for evacuation and is necessary only for those who are unable to leave the Island.

1) The City should make arrangements with the owners of all buildings on the Island which could serve as on-Island refuge, for the use of hallways and other common areas of buildings as emergency shelters. Such areas should be stocked with emergency food, water and medical supplies. Such structures should be constructed on pilings, elevated above 13.5 feet msl, have wind resistant walls and roofs, be located back from the coastal high hazard area.

2) All future buildings that are of a type which have common spaces, should be developed in a manner amenable to use as an emergency shelter. Use of such areas should be agreed upon during the approval of such development.

3) The City should develop a City Hall or other municipal structure designed to serve as emergency on-Island refuge for the maximum number of persons commensurate with the other anticipated uses of such municipal structures.

Building Codes

The Sanibel Building Code should be amended to provide that:

1) All development on Sanibel shall be designed to withstand the wind and water pressures associated with a 100 year storm.

2) All development in the Gulf Beach and Gulf Ridge shall be carried out on piling foundations capable of withstanding wind and water forces associated with a 100 year storm.

3) Emergency potable water capacity shall be included in all structures containing more than 4 residential units, commercial structures of greater than 3,000 square feet of floor area, and hotels and motels.

Capital Improvements

1) The City should upgrade the Island circulation system to provide efficient access to the evacuation route unimpeded by flooding from the interior wetlands.

2) The City should construct a multipurpose municipal building which can be used for emergency refuge.

3) Additional emergency vehicles should be provided for use during a hurricane, as well as tree and utility pole removal equipment.

4) The City should develop and support an efficient and effective warning system.

5) The City should provide maximum feasible elevated refuge during the development of any other municipal structure.

Education and Study

1) The City should conduct an extensive educational program to maximize citizen understanding of the threat of hurricane and the appropriate responses thereto.

2) The City should encourage persons to respond to early warnings and hurricane watch in order to lessen the evacuation burden after a hurricane warning is issued.

3) The City should contact the National Weather Service and any other agency of government with expertise in the field of hurricanes and floods, and attempt to develop future studies and programs on the extent of the threat to Sanibel, the consequences of that threat and appropriate responses for Sanibel given its particularly vulnerable situation.

Section 2.1.2: Fire Safety

A. BACKGROUND DISCUSSION

Currently, fire-fighting equipment is located at the main station at Palm Ridge Road and an unmanned substation at Rabbit and Sanibel-Captiva Roads. The fire-fighting staff includes two (four imminently) paid personnel (administrative assistant and equipment captain) and fifteen volunteers (one of whom is the Fire Chief).

The service area includes the entire Sanibel Fire Control District, the boundaries of which coincide with the City of Sanibel. Future planning of fire protection services is currently tied closely to the Island Water Association Distribution System. Until recently, only one fire hydrant existed on Sanibel, the remainder of the Island being serviced by seven fill pipes which require a pumper back-up to provide adequate nozzle pressure. The Water Association anticipates the installation of hydrants throughout the Island to conform to requirements of Fire Insurance Underwriters. This is discussed in further detail in Section 2.2.7, Fire. The existing equipment, which is also described in Section 2.2.7, provides pumper capabilities and reserve tank equipment sufficient to serve areas not served by hydrants or fill pipes, or too far from bodies of water which may be tapped with a portable pump.

Future demands of the Fire Department will be most critical within the interior portions of the Island that are not in close proximity to a body of water or fill pipes. Some areas fall beyond the recommended response distance of three miles. At the east end of the Island, approximately 500 dwelling units and 13 commercial establishments lie beyond this 3 mile radius. Plans and recommendations to improve fire service are discussed in Section 2.2.7 of this report.

Fig. 1, "Geological Sections," referred to in the text on this page, appears as Fig. 8 in the Hydrology Appendix.

B. WILD FIRES

Certain areas of Sanibel are particularly prone to large recurring fires. These fires are a natural occurrence in low-lying areas of the interior during periods of drought and are an important factor in the ecology of the interior wetland. Low-lying areas within the interior wetland are dependent on fire to burn off accumulated dead plants, to release nutrients to the soil, and to kill invading woody shrubs and trees. Fire stimulates healthy vegetative regrowth, thereby maintaining the flood storage capacity of the wetland and benefitting wildlife.

When man chooses to live in this environment, fire becomes a potential hazard rather than a resource and man's activities even increase the chances of fire.

It is paradoxical that man both inhibits fire and increases the intensity and frequency of fire. When fires are inhibited by man, dense, highly flammable debris accumulates on the ground. This extensive "build-up" of fuel rarely occurs in nature where periodic fires burn off accumulated debris. In addition, man is a primary cause of fire. Thus the presence of human habitation in certain areas of Sanibel has increased both the likelihood of intense, destructive fires and the hazard to human life and property. Two large, intense fires in the interior wetlands occurred during the past five years. Both fires swept over extensive areas of the interior and burned out of control for hours before they were brought under control. Fortunately these fires were controlled before they reached areas of dense residential development. Further development of this fire hazard area must be limited and restricted. Measures must be taken both in existing developments and in planning new residential developments to reduce hazard to life and property. New development should be confined to the edges of the interior wetland basins in the upland area. Hazard should be reduced by a management program of controlled burning and maintenance of high water levels. Buffer zones should be maintained around areas of residential or commercial development, and water pressure should be maintained at sufficient levels for efficient fire fighting. Proper access for fire fighting equipment should be provided and adequate standards such as road widths should be observed. The City should consult with the Florida Forest Service to establish a fire management program and to determine adequate safety standards.

C. OTHER FIRES

Accidental fire in buildings is potentially a major problem with respect to protection of residents and property because of inadequate facilities and fire-fighting personnel. The major shortcomings today are the absence of adequate water pressure and hydrants in close proximity to the densely developed sections of the Island. In particular, multi-story buildings pose a special problem in that several dwellings are not accessible to fire-fighting or rescue equipment. Problems of access are further complicated because several buildings do not have sufficient areas of stable paved areas that can support heavy fire-fighting equipment.

D. PLAN FOR FIRE SAFETY

The City should coordinate its activities with the Fire District to assure that adequate fire protection and safety are afforded the citizens of Sanibel.

Part 2.2: Human Support Systems

Section 2.2.1: Water Supply

A. BACKGROUND DISCUSSION

Adequate supply of fresh water is a major constraint upon future growth and development in the City of Sanibel. The hydrologic element of the Island is basically composed of surface water bodies, a water table aquifer, a shallow artesian aquifer, the Lower Hawthorn Aquifer and the Suwannee Aquifer. (See figure 1 which is a log of the geologic formations and aquifers underlying Sanibel.) The Suwannee and shallow artesian aquifers and the upper part of the Lower Hawthorn Aquifer contain saline water with more dissolved solids than it is considered economically acceptable to treat. The surface water bodies and the water table aquifer contain substantial quantities of both saline and relatively non-saline water, however the use of these bodies as a potable water source is extremely limited because of their importance to the continued viability of vegetation and wildlife on the Island, the control of mosquitoes, and the bodies' geologic and hydrologic character (See figure 2). The Lower Hawthorn Aquifer is the current source of the domestic water supply for Island residents. The Island Water Association owns and operates the public water system on Sanibel.

Prior to 1973, the I.W.A. purchased water from the Pine Island Water Association which tapped a shallow fresh water aquifer on the mainland. However, escalated growth on Sanibel in the early 1970's increased demand, and supply problems developed, largely associated with decreased yield and increasing salinity of the mainland well water. In November of 1973, the Island Water Association put a brackish water treatment plant into service on Sanibel, utilizing an electrodialysis demineralization or desalination process to treat water from wells 500-600 plus feet in the Lower Hawthorn Aquifer. The Lower Hawthorn is a part of the Floridan Aquifer, a state and regional water resource which is recharged in the center of the State. The Island Water Association plant has a capacity of 2.1 million gallons and serves Captiva as well as Sanibel. The fixed connection between the Pine Island Water Association and the Island Water Association is in place and maintained by both associations for emergency use. A 2 million gallon treated water storage reservoir is located at the I.W.A. plant and a second 2 million gallon reservoir is located east of Dixie Beach Blvd. The I.W.A. is currently undertaking an expansion program of treatment plant and distribution systems intended to increase system capacity to approximately 7000 connections (adequate to serve about 6000 dwelling units on Sanibel with the remaining connections used for commercial uses or for connections on Captiva).

The Island Water Association distributes the treated water from its treatment facilities directly to some areas of the Island and two remote pumping stations - the Sanibel Booster Station near the intersection of Periwinkle Way and Dixie Beach Boulevard, and the Captiva Substation located approximately one mile from the south end of Captiva Island on State Road 867. These two remote pumping facilities distribute water to the east end of Sanibel and to the north end of Captiva respectively.

B. FUTURE SUPPLY FACTORS

To date, the analysis of future water supply by the Island Water Association has dealt with the following factors:

1. the cost of pumping and treatment,
2. the cost of storage and distribution, and
3. the cost of securing well sites, drilling of wells, and piping cost to transport water to the treatment plants.

In the case of Sanibel the costs for well drilling and water transport are relatively easier to predict and plan for than are other costs. Cost figures relating to quality of water sources and the amount of treatment necessary to produce potable water are considerably more uncertain. Quality and quantity of water are major concerns, including:

1. The Island Water Association draws its supply from the lower level of the Lower Hawthorn Aquifer (See figure 1) at a depth of 500-650 feet. This is a slightly saline aquifer with chloride content ranging from 500-3000 ppm. The water body is approximately 200 feet thick and salinity generally increases with depth. The Lower Hawthorn Aquifer is artesian with a pressure of approximately 30 feet above mean sea level. Increasing withdrawals from the aquifer generally result in the inflow of more saline water.
2. Future growth in Lee County, especially in the western portion of the county will involve increased extraction of water from the Lower Hawthorn Aquifer which may have a substantial effect on the quality of the water in the Lower Hawthorn under Sanibel.
3. As salinity increases the extent of treatment required increases, with marked increase in cost and decrease in plant capacity.

Unfortunately the extent, quality, and hydrologic character of the Lower Hawthorn is not known. The City is cooperating with the U.S.G.S. and the Island Water Association to study the hydrology of the Lower Hawthorn in order to increase the understanding about the aquifer and its properties. The data that do exist suggest that the amount of water that will be available for Sanibel that can be treated with the existing equipment may be limited, and that amount may be reduced as a result of water extractions on the Island and inland. Cape Coral, the Estuaries and other proposed developments are anticipated to draw upon the Lower Hawthorn for water and this

Fig. 2, "Geological Sections," referred to in the text on this page, appears as Fig. 11 in the Hydrology Appendix.

increased use may adversely affect the quality of water in the aquifer beneath Sanibel.

Wells on the Island into the Lower Hawthorn indicate a high degree of variation in water quality from well to well, and the "fresh" water zone occurs at different depths in nearly every well. This introduces further uncertainties in attempting to develop additional water supply, particularly in the absence of adequate knowledge of aquifer properties. With highly saline water above, below and on several sides of the production zone, problems of saline water migration must be anticipated. Because of the prospective limitations on adequate future water supply several alternatives for supply and conservation were considered. These included desalination of sea water and such conservation measures as dual plumbing systems involving "gray water systems" for toilets and irrigation. At this time these are either economically unacceptable, hazardous to public health, or inapplicable or impractical on Sanibel and are therefore not now acceptable as policy for future planning. The water supply situation on Sanibel undoubtedly requires effective measures to be taken to minimize water use and conserve the supply. One important conservation element needing urgent attention is the plugging of existing unused wells tapping the Lower Hawthorn formation. These wells are contributing to the salinity of the City's water supply resource which, along with other factors, might ultimately render it useless.

No expansion of supply capacity should be considered until additional data on water quality and quantity in the Lower Hawthorn is available.

C. WATER SUPPLY AND FIRE PROTECTION †

D. THE PLAN FOR WATER SUPPLY

1. The City shall investigate the hydrology of the Lower Hawthorn Aquifer as soon as is reasonably possible.

2. No expansion of water treatment facilities or increased withdrawals of water from the Lower Hawthorn further than those described in this section should be considered until the study of the hydrology of the Lower Hawthorn is made.

3. The City should investigate the feasibility of acquiring the Island Water Association for operation as a municipality owned public utility.

4. The City should develop a water conservation plan including an educational program designed to encourage sound water conservation practice.

5. The City should develop a program which would lead to the plugging of all existing unused wells which are drawing water from the Lower Hawthorn Aquifer.

6. The City should continue to monitor and investigate the general hydrology of the Island.

7. The City should assist in the implementation of the improvements necessary to upgrade the Fire Protection system of the Island.

Section 2.2.2: Circulation

A. BACKGROUND DISCUSSION †

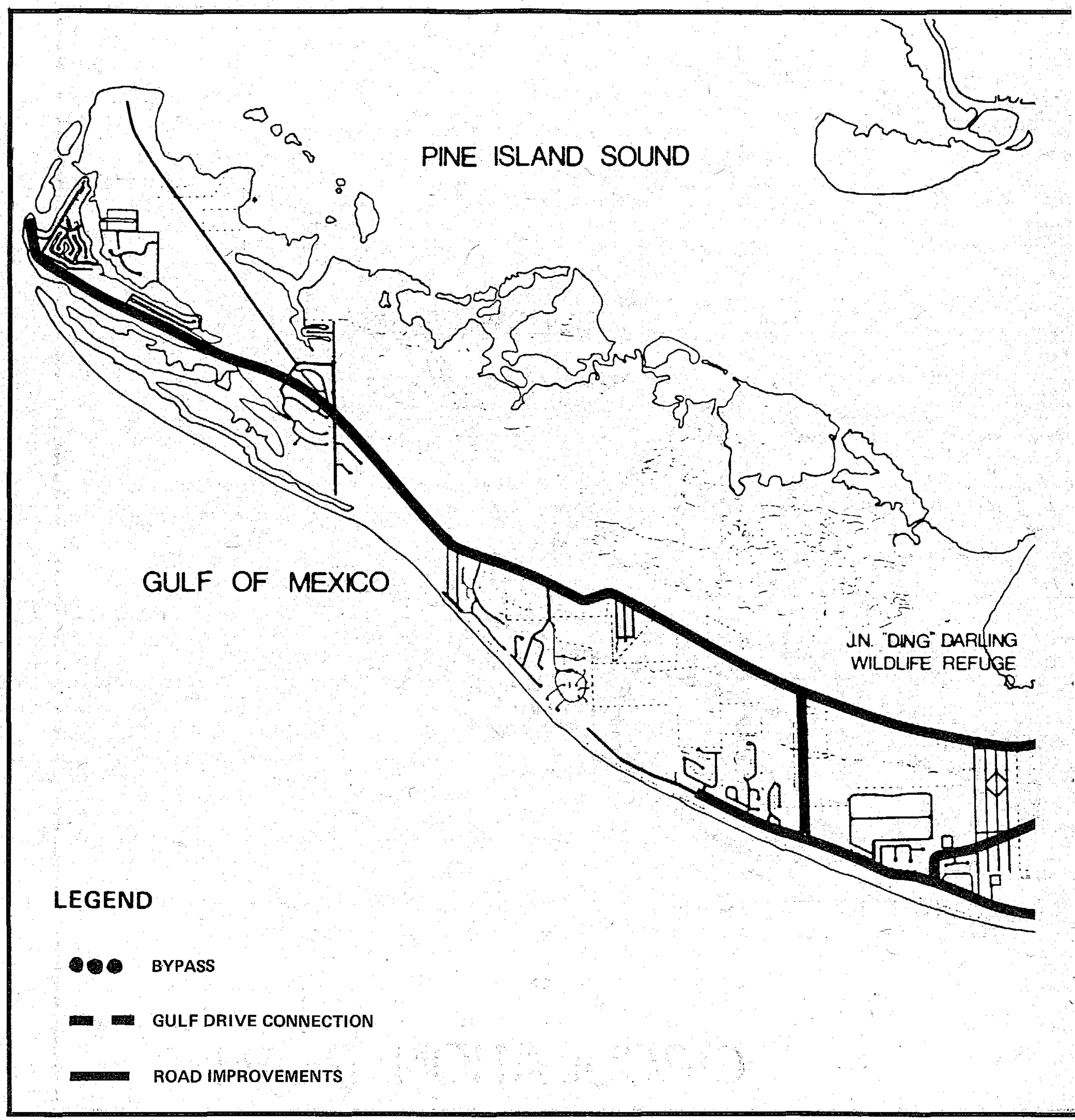
B. PLAN FOR CIRCULATION

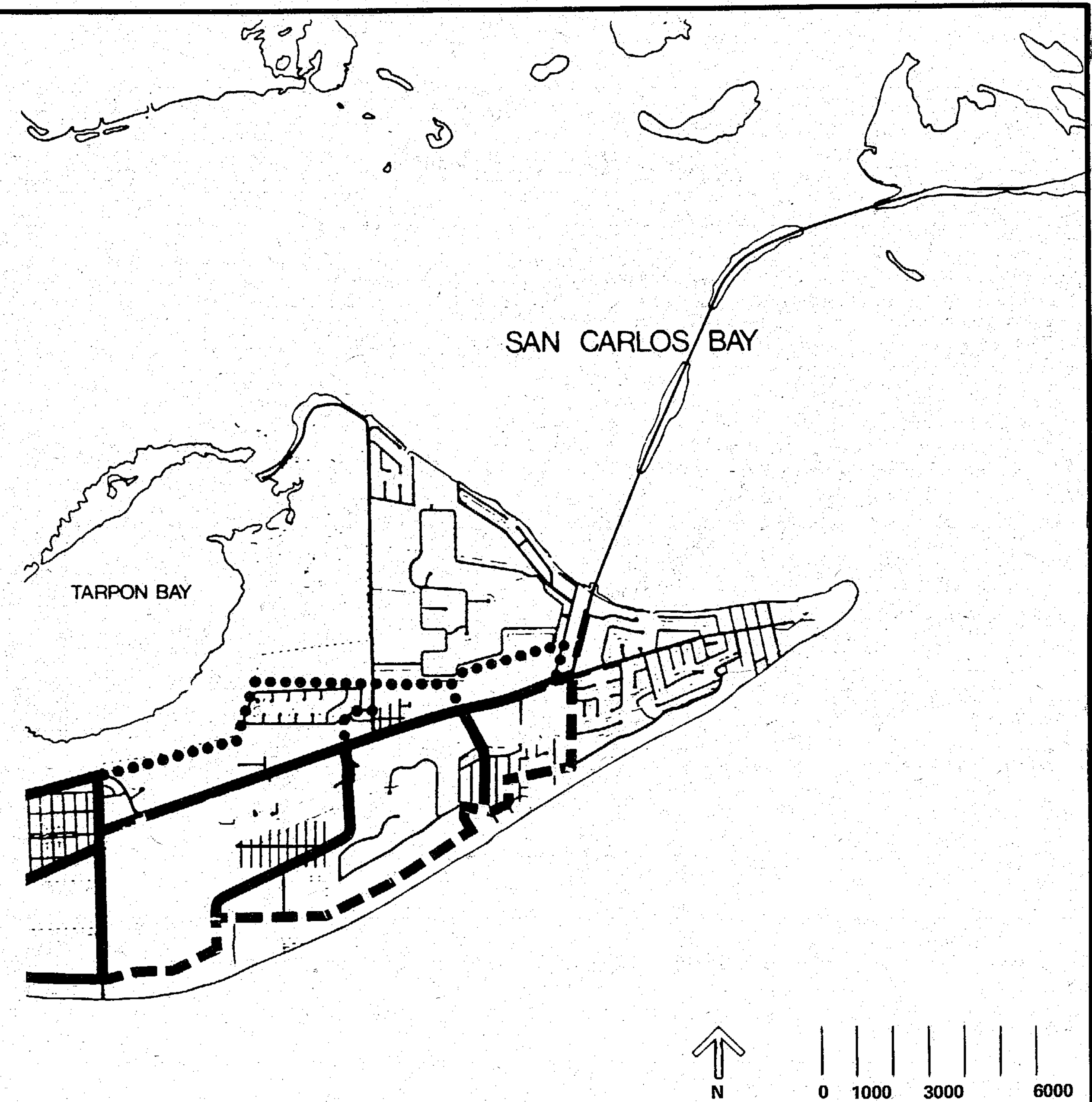
The plan recommended for traffic circulation is one that improves existing facilities up to a moderate Level of Service. Major improvements are proposed in terms of a new bypass road to take some of the traffic off Periwinkle Way, and continuation of Gulf Drive which serves the same purpose. As the improvements are implemented, operational characteristics can be further modified by speed limits, signaling, parking restrictions, turning movement restrictions and, at special situations, even one-way traffic flow and other measures necessitated by circulation problems.

Specific elements of the Plan for circulation are as follows:

1. All future circulation improvements shall be evaluated to assure that the objectives set forth in this section are supported and maintained.

2. The City should initiate a program which would provide for the undertaking of the roadway improvements identified previously in this section as first priority - short term improvements. The program should be structured to include planning and engineering studies, design standards, development plans and funding alternatives.


PINE ISLAND SOUND
GULF OF MEXICO
J.N. "DING" DARLING
WILDLIFE REFUGE
LEGEND
BYPASS
GULF DRIVE CONNECTION
ROAD IMPROVEMENTS



CIRCULATION PLAN

3. The City should, upon completion of the improvements identified as first priority, initiate studies to determine the appropriateness of undertaking the improvements previously identified as second priority.

4. The City should investigate the feasibility of alternate means of transit on the Island; in particular, bus service. Off-Island funding for such a project should be explored and a demonstration project should be included to test public response to such a service.

5. The use of bicycles should be encouraged by the City as an alternative form of transportation. This program should include the development of an extensive biking system throughout the Island.

Section 2.2.3: Sewage Treatment

A. BACKGROUND DISCUSSION

Treatment and recharge of waste water is extremely important to the water cycle of Sanibel. Along with recharge and runoff, it is an important source of water return to the ground and surface water systems, which is then utilized by man, plants, and animals. It is critical to the health and safety of residents that sewage effluent be treated to a high level and returned to the ground in a condition which does not risk polluting surface or ground water resources.

Presently, there is one major treatment plant on Sanibel, Jamestown Beachview, with over 975 hookups* and a planned system design for 3500 hookups*. The peak capacity is 1.2 million gallons per day. In addition to the Jamestown-Beachview plant, which serves parts of the major area of existing development on the east end of the Island, there are 20 package treatment plants. These primarily serve large subdivisions, condominiums, and commercial uses. Table "a" of the Phase I Report lists these plants, their service area, their capacity, type of discharge, number of connections, and current operating data in terms of BOD and SS. Several of the plants are operating within State standards[1] and Federal standards under the Federal Water Pollution Control Amendments of 1972 of 90%/90% for BOD**/SS***(suspended solids). Water quality tests[2] adjacent to some of them suggest that very high nutrient levels exist attributable at least in part to the sewage effluent discharge.

The rest of the Island relies on septic tanks for waste treatment. These septic tanks contribute to water pollution and pose potential health problems. Sewage may not be adequately treated because of low-lying ground, high water table and soils that are unsuitable for septic tanks and drainage fields.

Surface and ground water quality on Sanibel has been documented in Conservation Foundation studies[3] as generally poor, impaired by salt water intrusion and excessive nutrient loads. A majority of the Island's 4000 residential units are on septic tanks, many of which may afford inadequate treatment in very permeable soils or high water table. The USGS rates the Canaveral soil, which is most prevalent on Sanibel, as being severely restrictive for septic tank use.

Untreated or inadequately treated sewage effluent can cause serious health problems. Certain species of bacteria, protozoa and viruses in sewage can cause severe diseases in man. Enteric bacteria may include serious pathogens which could possibly exist in untreated or only partially-treated sewage. These include the salmonella bacteria, which can live in moist soils for as long as 70 days, and the organisms which cause bacillary dysentery, typhoid, and paratyphoid. Also disease can originate from protozoan organisms directly as a result of contamination by sewage. In addition to these threats to a community, entero viruses present another real health hazard. Although their presence in sewage does not guarantee an epidemic, they do present a constant threat of infection. Of significance here, for example, is hepatitis virus, which can exist in sewage polluted water, in shellfish living within that

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* Hookups - connections

** Biochemical Oxygen Demand

*** Suspended Solids

[1] Florida Air and Water Pollution Control Act, Florida Statutes 403.061 et seq.

[2] "Interior Wetlands Water Quality Management" Albert Veri Associates, Aug. 31, 1975, p.7

[3] "Sanibel Natural Systems Study, Preliminary Summary of Findings and Recommendations", The Conservation Foundation, September 16, 1975, pp. 2-17.

environment and eventually infect susceptible humans who drink the water or eat the shellfish.[1] In summary, there is evidence that in built up areas there is need for more effective treatment and disposal of sewage than by septic tanks.

B. SUMMARY OF EXISTING CONDITIONS

At present the 20 package plants on Sanibel service approximately 300 dwelling units and should if properly operated provide a higher level of treatment than septic tanks in terms of BOD and suspended solids. Several of them nevertheless cause or contribute to a problem in terms of excessive nutrients in the receiving waters. The Jamestown-Beachview plant which serves 975 connections in the East and East Central Sector of the Island has an expansion potential to 3500 connections.

The effluent from this plant conforms to State standards in terms of BOD and SS. However, underground flow from its inadequate treatment lagoons to the adjacent Sanibel River has caused the Florida Department of Environment Regulation to direct Jamestown-Beachview to seal the bottom of its lagoons. Dissolved nutrients, principally nitrogen and phosphorus, found in high concentration in the effluent from this secondary sewage treatment plant are capable of stimulating algal blooms. Such algal blooms may produce a variety of undesirable effects, including depressing dissolved oxygen levels below Federal water quality standards. Jamestown-Beachview has plans to include the package plants along Gulf Drive within its service area to the system.

At present, Jamestown-Beachview disposes of its effluent on the 18-hole golf course at Beachview Country Club Estates which is currently undeveloped. In the summer months this amounts to 500,000-600,000 gallons a day. The probable presence of pathogenic organisms prevents spraying of this effluent on lawns or the golf course of an adjacent residential development -- "The Dunes." However, appropriately treated effluent could be a valuable asset in view of the need for surface water replenishment in the fresh water management area.

[1] Health Hazards of the Human Environment, WHO 1972, rev. 1973, Chapter, "Soil and Land", p. 94.

Several alternatives for effluent disposal should be studied further including "sheet application;" "ridge and furrow," "ponding with percolation" and "spray irrigation following ground application." It may be necessary to have advanced treatment of the effluent prior to disposal, and detailed studies must show that soil conditions and hydrologic conditions will permit safe disposal in all seasons.

The problems of disposal of sewage effluent pose severe constraints on future development on Sanibel given that public health and environmental protection are primary goals of the City. On-site disposal with septic tanks is appropriate only in limited areas of the Island and must fully conform with the standards of the State of Florida, Chapter 10D-6. Disposal of treated effluent in San Carlos Bay or the Gulf of Mexico are environmentally and economically prohibitive as also is deep well injection of treated effluent to lower aquifers. The City must control future growth in line with the capacity of the disposal system along with strictly enforced controls for septic tanks and undertake detailed studies that include specific proposals for improving the quality of effluent from all package plants and provide suitable techniques for disposal of effluent.

The degree of waste water treatment before disposal is intimately associated with health and hygiene in the community. Also the effect of pre-treatment on the physical, biological and chemical characteristics of the waste water dictates to a large degree the appropriate means for disposal and potential use of the waste water.[1]

Exploration of means to integrate the planning and management of the fresh water system would help achieve maximum conservation of water. Such a managed system would be enhanced by the infiltration of treated effluent to the surface aquifer.

For very low density residential development which meets the performance standards, septic tanks could remove pathogenic organisms satisfactorily if suitably located where soils and water table may be suitable. For most development, however, only off-site treatment will be satisfactory. One method for providing such treatment would be for the City to acquire

[1] "Health and Hygiene Aspects of Spray Irrigation" by Charles A. Sorber and Kurt J. Guter. American Journal of Public Health, January, 1975.

Jamestown-Beachview plant from Jamestown-Beachview, upgrade the lagoon and tie in all uses in the City's East Sector and East Central Sector. Other methods are being examined by City consulting engineers and by an EPA grant-supported project. Only by such studies can a rational decision on these matters be made.

Preliminary estimates of costs for two options of providing extended and improved collection and sewage treatment for existing and future connections: (is as follows)

<u>Option 1, Acquire Jamestown Beachview System with Minor Improvements</u>

$1,900,000 -- if treatment plant is held at existing capacity of 1,200,000 mgd capacity

<u>Option 2, Acquisition and Major Improvement to Collection and Treatment</u>

$6,528,000 -- if treatment plant is increased to 1,625,000 mgd capacity and higher level of treatment is achieved and expansion of collection system.

Johnson Engineering prepared the cost estimates for these options as follows:

A. Acquisition of the Jamestown-Beachview Facilities:

1.	Replacement cost of plant and equipment:	$484,000
	Replacement cost of real estate and improvements:	100,000
	Replacement cost of lift stations:	525,000
	Replacement of sewer lines:	804,000
	Replacement cost of force mains:	216,000
	Replacement cost of professional services:	213,000
	Subtotal Replacement Cost:	$2,342,000
	Acquisition price at approximately 65% of replacement cost:	1,522,000

B. Update the Jamestown-Beachview Facilities to Serve Existing Capacity:

1.	Inspect, inventory and repair existing equipment and lines:	125,000
2.	Landscape site line, ponds, etc.:	100,000
3.	Personnel and equipment:	50,000
4.	Contingencies:	125,000
	Subtotal	$400,000
	Total for Option 1:	$1,922,000

C.	Collection System East of Tarpon Bay Road:	3,368,000
D.	Expansion of the Jamestown-Beachview Facility to 1,625,000 gallons per day, installation of equipment to obtain advanced treatment (Tertiary) and installation of master pumping facilities to the golf course	575,000
E.	Collection along Gulf Drive from Tarpon Bay to Rabbit Road	663,000
	Total for Option 2	$6,528,000

It is, of course, feasible that improvements to the collection and treatment systems could be financed and implemented without acquisition of Jamestown-Beachview by the City of Sanibel. In that case, the cost to Jamestown-Beachview will be approximately $400,000 for improvements in Plan A and $6,528,000 for Plan B improvements.

C. THE PLAN FOR SEWAGE TREATMENT

1. Provide an adequate waste water treatment system for each and every residential and commercial unit within the City.

2. Immediately investigate the desirability of public acquisition of the Jamestown-Beachview sewage collection and treatment system. The Jamestown-Beachview facility is located in the center of an extensive collection system and is located close to two possible effluent disposal areas. Although the plant appears well constructed and in good condition a thorough appraisal is necessary.

3. Develop and implement a program to provide increased waste water treatment capacity for the growth and development permitted under the Plan. In so doing, maintain close liaison with Federally sponsored studies for this region, in order to insure that the regional plan is acceptable to the City and that the City maintains its eligibility for Federal grant assistance.

4. Undertake detailed technical studies to determine acceptable systems and locations for disposal of treated effluent.

5. Connect all existing package plants to the central system as soon as is practically possible.

6. Require that all package plants be improved so that effluent meets Federal and State standards and wherever necessary shall exceed those standards to avoid negative environmental impacts.

7. Prohibit the use of septic tanks in all areas where sewers are available and in any event only where physical conditions of soils and hydrology permit such disposal according to State of Florida Department of Pollution Control, Chapter 10D-6 standards for individual sewage disposal facilities and environmental performance standards described in Article 3 of the Plan.

8. Implement a monitoring procedure to ensure that all sewage treatment facilities are constructed and managed in conformance with State and local standards.

D. CONCLUSION

The plan recommendations are closely related to the overall objectives of a Comprehensive Land Use Plan for Sanibel. The capacity of the sewage collection and treatment and effluent disposal systems is closely related to projected planned growth. Future growth will depend upon several unknown factors to provide adequate and safe effluent disposal. To bring present conditions of sewage treatment up to the standards required to maintain and improve environmental quality will incur costs not yet fully determined but expected by the City's planning consultants to be of the order of magnitude indicated by Sewage Treatment Option 2.

Section 2.2.4: Solid Waste †

Section 2.2.5: Power †

Section 2.2.6: Storm Drainage

A. BACKGROUND DISCUSSION

Storm water runoff characteristics are a direct function of the amount of precipitation, condition and density of vegetation or other ground cover, the structure and texture of the soil or other surface material and its saturation level. Topography also affects storm water flow, percolation, and overflow rates. Water infiltrates each soil type at a specific rate, characteristically rapid at first, then levelling off until it is no longer absorbed. If precipitation continues, depressions fill, water accumulates, and overland flow occurs.

Runoff is increased by urban development when there is a high coverage of impermeable surfaces such as roads, patios, roofs, parking lots and other hard areas. This causes rapid overland flow, and erosion of soils. Water can be an extremely powerful and destructive force on the landscape. Although surges of water from high frequency storms are not immediately devastating on the landscape, they do have long-term, negative effects such as the removal of the surface soil layer, loss of soil nutrients and ultimately loss of vegetation. This process often causes irretrievable damage to the land surface, as well as degrading water quality with increased sedimentation and pollution. Such conditions may require reclamation, particularly when erosion is so severe that it removes the lower soil horizons, which are more vulnerable to water transport. In addition to these impacts, overland flow also deprives the water table of replenishment, which would otherwise penetrate the surface.

Fortunately, the infiltration rate on Sanibel's shell and sand substrate is exceedingly high, and as a result, overland flow is almost negligible. Under natural conditions, rainwater quickly replenishes the ground water table and overland flow of water from one area to another would be virtually negligible. This condition, however, is not maintained in urban development areas unless storm water is managed by having adequate areas of permeable soil and vegetation.

Damage resulting from increased impermeable surfaces and improper drainage solutions have already been recorded on Sanibel primarily along the Gulf Beach. The majority of condominium developments along the Gulf Beach directs storm drainage from their roofs and parking lots through channels and pipes on to the beach. This practice has three very harmful impacts. First, the fresh water is not being recharged to the ground water in the Gulf Ridge Zone where it interfaces with the salt water system and diminishes the threat of further salt water intrusion from the Gulf. (See functional diagrams of subsurface water flow in discussion of Ecological Zones, Section 2.3.1.) Secondly, the peak discharges from these storm drainage systems are greater than those generated from overland flow under natural conditions. Therefore, harmful erosion of the beach and beach vegetation is caused. Thirdly, the pollutants and debris from parking lots are deposited on the beach, thus degrading one of the Island's most valuable resources.

The environmental damage caused by such inadequate storm damage systems on Sanibel represents a real threat to several valuable ecological functions on Sanibel, such as maintenance and recharge of the fresh water lens, maintenance of water quality, and maintenance of natural vegetation and wildlife habitats.

The method of dealing with storm water drainage so as to minimize harmful impact of urbanization on the environment is to preserve and utilize the inherent capabilities of the site to absorb water effectively with minor modifications to land configuration. By careful site planning and maximizing the areas of site that retain and absorb storm water, costly piping, channels and culverts can be reduced. A "Natural Drainage System" that is sympathetic to natural processes causes the least environmental disruption, and can be less costly to build and maintain. Most important, the problems and solutions are localized to the project site and not imposed on adjacent land.

In order to retain Sanibel's native vegetation and wildlife habitats, the existing ground water system must not be disrupted. It is therefore a policy of the City in this Comprehensive Plan that the storm water produced by five-year storm conditions will be collected and retained and recharged on the site of any urbanization.

Large open areas of highly permeable soils must be set aside as detention areas, catchment areas; vegetated swales and filter beds should be used to ameliorate the force of excess runoff and recharge it. Vegetated swales which follow the natural contour are effective and economical means of directing water flow.

The Natural Storm Drainage System can achieve the following:

1. Maximize recharge
2. Minimize runoff
3. Minimize erosion and siltation
4. Minimize vegetation removal
5. Minimize maintenance and drainage system costs
6. Improve water quality
7. Enhance flow in Sanibel River

An invaluable resource to the Island-wide natural drainage system is the interior wetland. This 3588 acre depression in the central area of Island roughly bordered by Periwinkle Way, Sanibel and Captiva Road on the north and Gulf Drive on the south provides an important role in terms of storm water storage, during both high frequency as well as more intense storms. The main drainage way of the interior wetland is the Sanibel River.

Historically, the Sanibel River was a semi-continuous slough system that originated in the vicinity of the present Tradewinds Subdivision and during high water conditions emptied into the Gulf of Mexico near the present "Colony" motel and apartments. In 1960 the River was channelized for mosquito control purposes. The primary objective was to concentrate the surface water in one channel and to maintain as constant a water level as possible. Water level control structures were installed at Tarpon Bay and at Beach Road, and are the only river outlets to salt water under normal conditions.

County roads through the interior wetlands crossed the river over bridges early in the Island's development. However, these bridges were eventually replaced by culverts and fill. In many cases the inverts of the culverts were placed at elevations higher than the normal level of the water in the river. These changes in invert elevations have caused unanticipated problems in the interior drainage system. The water level control structures existing today permit the intrusion of salt water which degrades water quality.

More importantly in terms of storm drainage and the health, safety and welfare of the Island's residents, constrictions in the interior drainage system cause flooding. During periods of heavy rainfall in the rainy season, moderate to severe flooding occurs in some areas. At times substantial portions of major highways are covered (see map of existing highway conditions, Section 2.2.2) often to a depth of six to eight inches. This is partly due to incorrectly sized and improperly placed culverts. The combination of improving intra-basin flow in the interior wetlands as well as raising the roads (see Section 2.2.2) will give greater flood protection to emergency evacuation routes in the event of a hurricane. Constricting culverts reduce the velocity of the flow in the river, and effectively prevent adequate flushing of salt water from the interior of the Island because of the density relationship between fresh and salt water. Typically this results in the discharge from the Island of the overlying fresh water and the retainage of the lower strata of salt water, thus greatly reducing water quality in the interior wetlands.

In their 1975 study dealing with ways in which to rejuvenate drainage in the interior wetlands, Johnson Engineering pursued the following objectives:[1]

Primary:

Preserve the Sanibel River as a natural, free-flowing fresh water system.

Supporting:

1. Remove bottlenecks in the existing channel to improve the flood control system.
2. Improve the existing riverine system to provide for a continuous free-flowing stream.
3. Reverse the existing trend toward salt water intrusion. Return the River to a fresh water environment, ultimately purging all salt water from the system.
4. Establish a plan for the protection and management of the Sanibel River to insure the preservation of this natural resource for the enjoyment of future generations.[2]

[1] "Preliminary Plan, Sanibel Island Fresh Water Management Area" for the Sanibel-Captiva Conservation Foundation, Inc., Johnson Engineering, Inc., 1975.

[2] Ibid.

The condition of the interior wetlands storm drainage system can be improved and numerous other benefits gained by the City if the following proposals are carried out:

1. Culverts under the following roads should be replaced with culverts or culvert pipes to permit flow at all levels of the River:

   .Beach Road
   .Sanibel-Captiva Road
   .Tarpon Bay Road
   .Casa Ybel Road
   .Rabbit Road

2. Rebuild the water control structures at Tarpon Bay and at Beach Road so as to prevent salt water intrusion.

The preliminary cost estimates related to this Plan for storm water drainage and flood control in the interior wetlands are as follows:

1. Water Control and Drainage Structures:	
.Tarpon Bay Weir Structure	$100,000
.Beach Road Weir Structure	60,000
.Beach Road Box Culvert	67,000
.Sanibel-Captiva Road Box Culvert	112,000
.Tarpon Bay Road Culvert Pipe	12,000
.Casa Ybel Road Culvert Pipe	10,000
.Rabbit Road Culvert Pipe	10,000
2. Miscellaneous Structures	
.Culvert Pipes	30,000
3. Channel Improvements	
.Removal of major blockages only	20,000
TOTAL COST:	$421,000[1]

It is presumed that this special drainage and flood control project will qualify for grants in aid from off-Island resources. The Federal government's Department of Housing and Urban Development, the State of Florida Department of Natural Resources and Lee County Mosquito Control District are all potential sources of

[1] Johnson Engineering, op.cit.

funding. Even if these off-Island sources are not forthcoming, the project could be funded locally with a debt service of approximately .15 mills.

B. Plan For Storm Drainage

1. The drainage improvements described in the Preliminary Plan for the Sanibel Island Fresh Water Management Area should be implemented.

2. To complement the drainage improvements, the following policies should be observed:

   a) The Storm Drainage System will provide for the gradual and dispersed drainage of excess surface runoff such that runoff from within the boundaries of the proposed development will approximate natural rates, volumes, and direction of flow from that parcel.

   b) The Storm Drainage System will not result in any surface runoff across or onto the beach.

   c) The Storm Drainage System will not reduce the volume or increase the rate of water flow from any parcel draining to the interior wetland or Fresh Water Management Area.

3. A City appointed committee should participate and advise in the consideration of fresh water management programs.

Section 2.2.7: Fire †

Section 2.2.8: Police †

Section 2.2.9: Medical Facilities and Public Health †

Section 2.2.10: Education †

Section 2.2.11: Insect Control

A. BACKGROUND DISCUSSION

1. Mosquitoes

Florida legislation establishes procedures for mosquito and other arthropod control.[1] Chapter 388 allows creation of districts for the purpose of raising money through taxation. These districts can adhere to city, town or county boundaries or any portions thereof. A district must submit its control plan to the Division of Health, which then must be approved before operations begin. The Board of Commissioners of such a district may condemn land needed within the district. A special Act, Chapter, 67-1630, creates the Lee County Mosquito Control District. Ultimate responsibility for suppressing mosquitoes is in the hands of the Board of Commissioners of the Lee County Mosquito Control District. District activities are coordinated with the requirements of the County Health Department.

The following text provided by Lee County Mosquito Control District describes the problems and opportunities for mosquito control on Sanibel:

"The tropical climate that is the essence of the island's appeal also results in a lesser known distinction. Sanibel is the largest producer of salt marsh mosquitoes in the world. Although more than twenty different species of mosquitoes are collected during a normal year, _Aedes taeniorhynchus_ is the principal problem. This mosquito and the island itself, has been the object of extensive study by highly qualified scientists for many years.

"During the years 1948-52 the Florida State Board of Health carried out a major mosquito research project on Sanibel, and in 1953, Dr. Maurice Provost, Director of the Florida Medical Entomology Laboratory, published a report of this work entitled "The Water Table on Sanibel Island." That comprehensive study, and the report by Dr. Provost, detailed the basis for control of _Aedes taeniorhynchus_ on the island.

"In 1958, the Lee County Mosquito Control District was created to provide control of mosquitoes in almost all of Lee County, including Sanibel. This special district is governed by a Board of six commissioners, who are elected on a non-partisan basis for four year terms. Chapter 67-1630, Laws of Florida, provides that one member of the Board must be a resident of either Sanibel or Captiva Island. One of the first actions of the Board of Commissioners was to

[1] In accordance with State Law 67-1629

implement Dr. Provost's basic plan for Sanibel; and for the past eighteen years a significant portion of the District's effort, far in excess of the island's financial contribution to the program, has been expended on Sanibel.

"The salt marsh mosquito problem is two-fold. The interior fresh water swales originally were the most prolific producers of mosquitoes, with the semi-tidal mangrove areas on the bay side of the island constituting, in comparison, somewhat less a problem. Dr. Provost's plan for the interior swales was simple, and rather easy to accomplish. Taeniorhynchus is a flood water mosquito - i.e.,the female deposists eggs on damp soil rather than in water. These eggs can lay dormant for long periods, and hatch only when they are flooded - normally by rainwater or in the mangrove areas by high tides. Thus, control of this mosquito in the interior of the island is primarily a matter of maintaining a high water table. Dr. Provost recommended thirty inches above the mean low water, or about two feet above sea level, as a minumum. The District has attempted to maintain this level over the years, and has encountered three problems. First, evaporation and transpiration on the island are tremendous. Dr. Provost estimated that this water loss can exceed one inch a day. Second, the island is porous, and the water literally leaks out. Third, residential and other building in low areas has resulted in strong resistance by some property owners to a high water table. In spite of these problems, the water management program carried out by the District has accomplished the purpose intended, and extensive salt marsh mosquito breeding in the interior wetlands is a thing of the past. Several groups on the island are now pushing for a constant water table higher than that realized up to now. If this can be accomplished, the interior wetlands will be relatively unimportant as a producer of Aedes taeniorhynchus in the future.

"The semi-tidal mangrove areas are an entirely different problem. A portion of this area was eliminated when the Lee County Mosquito Control District constructed what is now a five mile wildlife drive through the Ding Darling Refuge. In addition, a system of ditches in the major breeding areas has been accomplished over a period of years. These ditches serve as permanent reservoirs where fish may live when the main body of the marsh is dry. Not only does this provide minnow access to mosquito larvae, these ditches have enlarged and enhanced the marshes as nursery or spawning areas for many species of fish, shrimp, and crab. Unfortunately, permit requirements enacted to control rampant development in coastal areas have effectively stopped mosquito control work of this type.

"Since extensive mosquito breeding areas will continue to exist, an organized control program is necessary. The Lee County Mosquito Control District uses helicopters to determine the extent of mosquito breeding on over seventy-five thousand acres of Lee County coastal marshes. When mosquito larvae are present in great numbers, it is necessary to larvicide - i.e.,to apply a material to the water to kill the immature mosquitoes before they emerge as adults The comprehensive program of salt marsh inspections, and subsequent larviciding when necessary is presently the most efficient and effective work carried out by the District. However, even with extensive larvidicing, many adult mosquitoes emerge to plague the residents of the island. When this happens, the District carries out a limited program for chemical control of adult mosquitoes. There are a number of disadvantages to this type of work. Frequently, results are unpredictable and erratic. Applications of chemicals often must be repeated as reinfestation of populated areas occurs from migrating flights of mosquitoes, and resistance to certain insecticides is a very real problem. These factors, together with the extremely high cost involved, combine to keep chemical control of adult mosquitoes to a minimum which will provide acceptable control. It is the policy of the Board to restrict this work to the areas and times of greatest need.

"To assure that adulticiding is carried out to the best advantage, truck traps are used to sample adult mosquito populations seven nights each week during the summer months. Mosquitoes collected are transferred to the District's laboratory, where they are identified as to species and sex. This information is used as a yardstick to determine where adult control work should take place and when. Male flood water mosquitoes emerge about one to two days sooner than the females do. Therefore, if a trap collection contains a significant number of male mosquitoes, it is too soon to adulticide, because it is certain that many female mosquitoes are still in the larval stages, and a premature application of insecticide would be a waste of the taxpayers' money. In addition, the staff carries out several tests each year to detect possible resistance to insecticides. Live adult mosquitoes are collected and transferred to an insectary, located in the laboratory. Here they are given a blood meal, to assure that a large quantity of eggs will be laid by the female mosquitoes. These eggs will be hatched, and the larvae treated with various concentrations of insecticide. This determines the susceptibility of Sanibel mosquitoes to each insecticide that the District uses. In this way, the minimum dosage necessary for adequate control is determined. These tests also reveal when resistance to particular material is developing. If this occurs, use of that insecticide would be terminated.

"To keep abreast of the latest developments in mosquito control work, the District frequently cooperates with established research agencies. Presently, this work is being expanded to evaluate the potential of biotic agents such as pathogens, parasites and predators, as well as genetic manipulation of mosquitoes. All of these biological controls, have undergone thorough study by research groups. Many show excellent potential in the laboratory, and are ready for testing under actual field conditions. The District has entered into an agreement with the

USDA, Gulf Coast Mosquito Research Laboratory, Lake Charles, Louisiana, for field research on Reesimermis nielseni, a mermithi nematode, and with the World Health Organization Collaborating Center for Biological Control on Bacillus sphaericus. In the past, research of this type has been restricted to controls of human diseases. This new program will consider the potential for reducing overall pest mosquito populations as well, and will be the first large scale attempt to use biological controls in an organized mosquito abatement program. Cooperative work of this type assures the residents that the program carried out by the Lee County Mosquito Control District is constantly updated, and that the benefits of new research are incorporated here, even as they are being developed."[1a]

2. Sandflies

Mosquitoes are not the only pests on Sanibel. Sandflies are becoming an increasingly serious problem "for which there is rarely any easy, cheap or fully effective remedy.[1b] The use of personal insect repellants, treated screens and air conditioning has had good results in maintaining a comfortable balance with these insects.

[1a] Lee County Mosquito Control District - March 1976.

[1b] John R. Linley and John B. Davies, Sandflies and Tourism in Florida and the Bahamas and Caribbean Area.

C. THE PLAN FOR MOSQUITO CONTROL ON SANIBEL

A totally ecological approach requires strict adherence to the following:

1. A consistent high water table in the interior wetlands should be maintained - (in general the higher the better, consistent with other land uses). This will virtually eliminate salt marsh mosquito breeding in these areas.

2. Drainage patterns should be kept as natural as possible. The proposed improvements to the drainage system should be carried out (see Section 2-206 on Storm Drainage) in order to increase intra-basin flow. The drainage improvements will enable retention of a more consistent water level in the Interior Wetlands, thus exposing less area to the successful hatching of mosquito larvae.

3. A population of larvivorous fish should be maintained wherever possible on the Island.

4. Mosquitoes should be controlled in the larval stages whenever possible, generally keeping the Island free of biting adults. Larvicides should be chosen on the basis of safety both to humans and wildlife and applied in a lawful manner.

5. Chemical control of adults should be kept to a minimum, consistent with acceptable control and lawful application.

6. Research should be encouraged which should lead to alternate methods of control, thereby avoiding dependence on a chemically oriented mosquito control program.

7. City Manager should be directed to obtain the best Federal and State and Local advice concerning mosquito control on Sanibel.

Part 2.3: Protection of Natural, Environmental, Economic and Scenic Resources

Section 2.3.1: Preservation of Ecological Functions Relating to Health, Safety and Welfare

A. BACKGROUND DISCUSSION

Sanibel's natural environment performs many invaluable functions for man at no cost; it buffers storm winds and flood tides, stabilizes the shoreline, purifies water, and maintains a fresh water system which supports a rich wildlife and lush vegetation. These functions support the health, safety and welfare of every Sanibel resident and must be preserved.

Different parts of the Island contribute in varying degrees to each particular function. For planning purposes the Island has therefore been divided into ecological zones, each with particular characteristics, specific contributions to health, safety and welfare functions, and varying tolerance to the range of man's activities. Six ecological zones have been identified on Sanibel, three of which are further divided into sub-areas -- Gulf Beach, Gulf Beach Ridge, Interior Wetland Basin, Mid-Island Ridges, Mangroves and Bay Beach. The Gulf Beach Zone is subdivided into Gulf Front Beach and Gulf Back Beach and the Interior Wetland Basin is composed of Upland and Lowland sub-areas. A Special Blind Pass Zone is designated in the Blind Pass area.

The following is a brief description of each ecological zone:

Gulf Beach Zone

The Gulf Beach Zone includes all land seaward of the Coastal Construction Setback Line. There are two sub-areas within this zone:

<u>Gulf Front Beach</u>: This is the most active beach zone and includes the area between mean high water and the City's boundary 300 feet offshore. Sand in this zone is in constant motion. Sand migrates between the berm and offshore bars and is transported up and down the coast by longshore currents. Examination of historical surveys and aerial photographs over the past thirty years shows that erosion and accretion of sand along the beaches are cyclical in many areas with a 20 or 40 year period before the process is changed. This zone maintains several functions critical to public health, safety and welfare. It is the Island's first defense in storm and flood when the impact of waves erodes the sand reservoir in the berm. The natural form of the Gulf Beach Zone is a response to natural processes of wind, currents and waves. Undisturbed, it is in a state of balance with natural

	ECOLOGICAL ZONE	WEST SECTOR	WEST CENTRAL SECTOR	EAST CENTRAL SECTOR	EAST SECTOR	TOTALS
A	GULF BEACH	45	117	55	42	259
B	BAY BEACH	–	–	40	18	58
C	MANGROVE	416	–	339	13	768
D_1	INT. WETLAND: LOWLAND	59	504	364	–	927
D_2	INT. WETLAND: UPLAND	82	410	438	–	930
E_1	SPECIAL BLIND PASS AREA	303	–	–	–	303
E_2	GULF BEACH RIDGE	53	200	160	67	480
F	MID ISLAND RIDGE	383	–	340	75	798
G	FILLED LAND	142	446	878	383	1849
	TOTAL	1483	1677	2614	598	6372

Note: Acreage approximate.

Source: WMRT

forces, thus "maintaining" the shoreline. This area also supports the marine life for which Sanibel is famous, and is an important feeding area for Island wildlife.

Gulf Back Beach: This zone, though less dynamic than the front beach, also absorbs considerable impact from storm generated wind and waves. It is a reservoir of sand which may be eroded after the berm in a severe storm, thus protecting property further inland on the Beach Ridge. The dunes are an important nesting area for wildlife, the loggerhead turtle being a prime example. The vegetation of the Back Beach is particularly important, as it stabilizes and holds the sand.

Both parts of the Gulf Beach Zone have a very low tolerance to man's activities. Removal of sand, disposal of storm water runoff, excessive foot traffic or any vehicular traffic can quickly induce major erosion and other impacts on the beach. Strict regulations are therefore required to maintain this zone. Removal of sediments from the beach and construction of any sort which would change the configuration of the beach or inhibit sand movement should be prohibited. Wildlife access to the beach should be maintained and public access to the beach should be confined to elevated walkways. Because of their shallow root system, Australian pines are not a suitable plant in this zone and should be selectively thinned and removed from the beach zone so that hardy native dune vegetation can be introduced and managed.

Bay Beach Zone

The Bay Beach Zone extends along the Island's bay shoreline and is also an "active beach" zone. Although the Bay Beach is a lower energy beach than the Gulf Beach, it nevertheless serves the same valuable storm and flood protection, shoreline stabilization, marine life and wildlife habitat and feeding functions. The natural processes are similar and so, too, are the constraints to development. Regulations, the same as those outlined for the Gulf Beach Zone in the performance standards, are required to maintain the functions of this zone.

Mangrove Zone

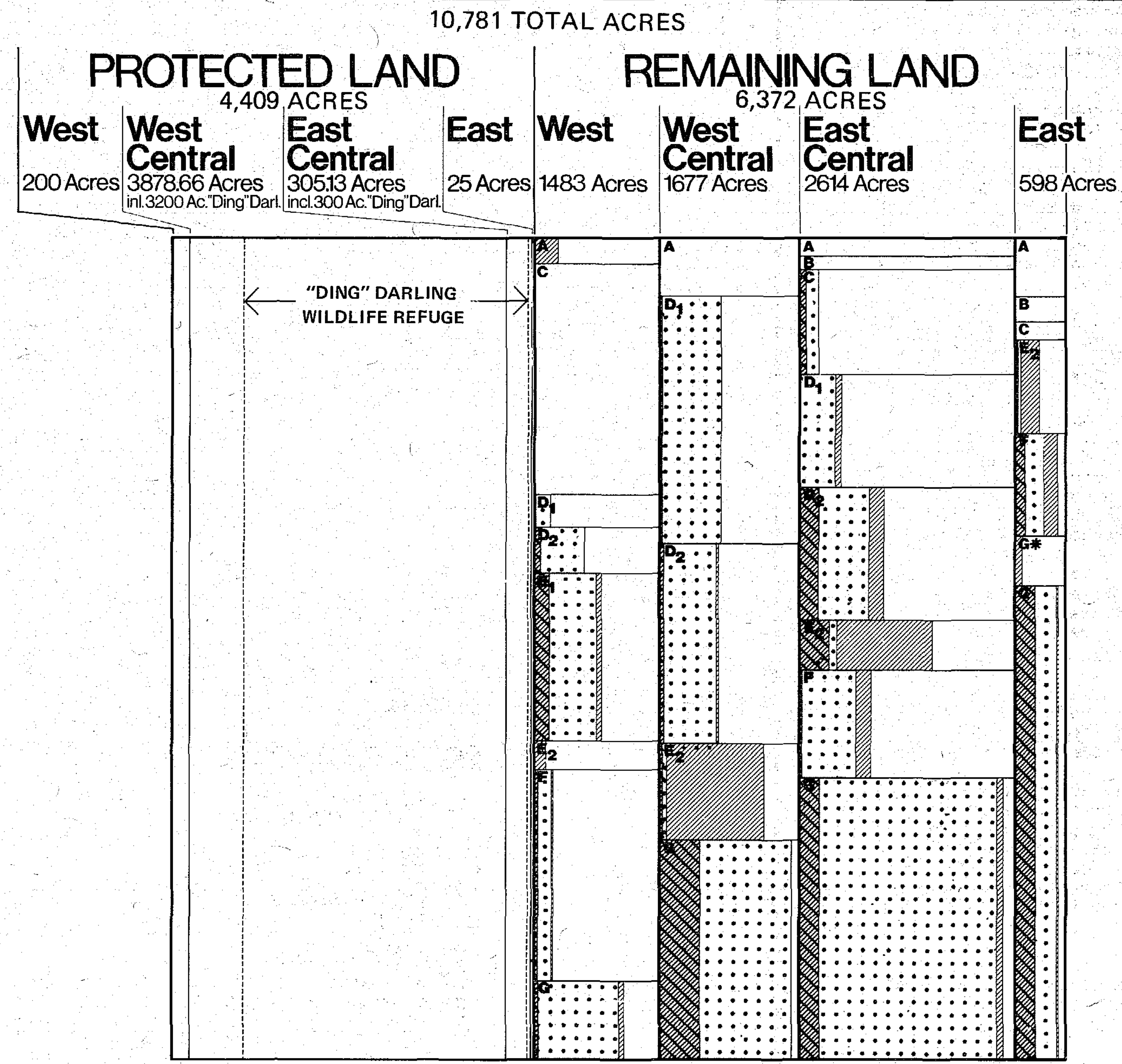
The Mangrove Zone includes as well as black and reds all buttonwood and white mangrove areas, and the tidal flats within and around them. This zone includes most of the bay portions of Sanibel. In ecological and energy terms, it is difficult to conceive of a more valuable and efficient zone. The number of jobs done for man at no cost (save the price of preserving mangroves) is not exceeded by

LEGEND

- ACRES DEVELOPED IN SUBDIVIDED LAND
- ACRES REMAINING IN SUBDIVIDED LAND
- ACRES DEVELOPED ELSEWHERE
- ACRES REMAINING ELSEWHERE

ECOLOGICAL ZONES:

A GULF BEACH
B BAY BEACH
C MANGROVE
D1 INTERIOR WETLAND BASIN: LOWLAND
D2 INTERIOR WETLAND BASIN: UPLAND
E1 GULF BEACH RIDGE: BLIND PASS AREA
E2 GULF BEACH RIDGE
F MID-ISLAND RIDGE
G FILLED LAND
G* FILLED LAND NEAR CAUSEWAY



Source: WMRT

ACRES DEVELOPED BY SECTOR and ECOLOGICAL ZONE

any other zone. Mangroves protect public health, safety and welfare by buffering storm winds and flood tides from the bay, by stabilizing and extending the shoreline, by maintaining and improving water quality, by maintaining the highly productive marine ecosystem, and providing food, shelter and nesting areas for wildlife. A more complete description of the different types of mangroves is included in Coastal Zone, Section 2.3.2 of the Plan. This zone also has a low tolerance for alteration by man. Its existence is dependent on the regulation of activities in adjacent areas. Clearing of mangroves and excavation or filling in mangove areas are governed by the performance standards in Article 3 of the Plan.

Interior Wetland Basin Zone

The Interior Wetland Basin Zone is the interior storm water drainage bowl of the Island which has formed as a fresh water reservoir. It is composed of parallel systems of ridges and swales with corresponding bands of vegetation that either tolerate the persistent wetness of the swales or fluctuating conditions of the ridges. There are two sub-areas within this zone -- lowland wetlands and upland wetlands. The lowland area is composed of low ridges and wide swales; the upland consists of higher, broader ridges and narrower swales. The entire zone is the major recharge area for the fresh water aquifer.

> Lowland Interior Wetland: The lowland area typically experiences extended periods of flooding each year. Since it is lower than the surrounding area it serves as a storage area for flood waters until they are absorbed into the aquifer. So long as the elevations in the lowlands are not substantially increased by filling, this area will protect the ridge areas from flooding and maintain recharge to the fresh water lens. This zone has a "fire ecology." Periodic fires burn off accumulated dead plants, release nutrients to the soil and kill invading woody shrubs and trees. These large, recurring fires are a hazard to human settlement in this area but are essential to the maintenance of this zone. This area also has the capacity to maintain and improve water quality, and provides food, shelter, water and nesting areas to many of Sanibel's most renowned wildlife, including the American alligator. Excavation of the aquiclude[1], filling, the impediment or impoundment of natural water flow, the disruption or alteration of natural drainage channels, and the use of septic tanks is greatly restricted. Impervious paving and the clearance of native vegetation is controlled. Storm runoff from paved or developed areas is to be retarded and dispersed slowly to the natural hydrologic system. Programs of fire management and water level control should be instituted. Wildlife corridors should be established connecting nature preserves to the Sanibel River, and providing for wildlife movement along the River.

> Upland Interior Wetland: The upland area is characterized by less frequent flooding than the lowland area and more upland vegetation types. It is more tolerant to human activities and therefore is easier for development to meet the same performance standards as those for the lowland. Filling, excavation of the aquiclude and the use of septic tanks are strictly restricted. The impoundment of natural water flow or disruption of natural drainage channels is also controlled. Wildlife corridors should be established connecting nature preserves to the Sanibel River.

The City should conduct a study to determine the optimum water level elevation in the Interior Wetlands Zone. The demands of the fresh water system, mosquito control, fire control, and flooding should all be considered in determining this elevation. Detailed engineering studies are necessary to determine the best condition to achieve balance between the major objectives. The City should establish a board to oversee the preparation of a study for the Fresh Water Management areas as well as recommend a policy and control budget required for the implementation of a management program.

Gulf Beach Ridge Zone

The Gulf Beach Ridge Zone is the major ridge dividing the Gulf and the Interior Wetland Basin. It extends to the western end of the Island and includes upland areas of Blind Pass Keys. The Blind Pass area is included in this zone because of its very recent formation. Thirty years ago Silver Key was in the Gulf Beach Zone and as this area is highly unstable and susceptible to dramatic change, it may be beach again in the future. The Gulf Beach Ridge Zone serves many valuable functions in the maintenance of the health, safety and welfare of Sanibel residents. The ridge buffers flood tides and storm winds and prevents increased flooding

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[1] The aquiclude is the clay layer which separates the shallow saline aquifer and the water table aquifer.

in the interior (unless overtopped by waves) and contributes to shoreline stabilization. Maintenance of elevation and vegetation are the keys to the protection of these valuable functions. Vegetation stabilizes the ridge and prevents erosion of the soil. Much fresh water runoff enters the ground in the Beach Ridge Zone, halting inward intrusion of salt water from the Gulf and thus maintaining the extent of the fresh water lens. Soil and vegetation in the ridge filter runoff and protect water quality.

Although this zone is crucial to health, safety and welfare, it is more tolerant to residential development than other more sensitive zones on the Island. The one area of exception is the Blind Pass area, which is extremely intolerant to alteration and hazardous to human settlement and is discussed separately later. Excavation which results in lowering the elevation of the ridge or in penetration of the aquiclude is prohibited. Disruption or alteration of natural drainage channels and the use of septic tanks is severely restricted. Storm runoff from paved or developed areas is to be retarded and dispersed slowly to the natural hydrologic system. Storm runoff from paved or developed areas to the beach is strictly controlled. Impervious paving and clearance of native vegetation is restricted and native beach ridge vegetation should be planted in areas which are not well vegetated.

Special Blind Pass Zone: The Blind Pass area is the youngest and the least stable part of the Island. It is an inlet system very susceptible to dramatic change both in a storm and over time. This has been borne out by Stanley Riggs[1] in a study cited in Morrill and Byle[2] and through aerial photographs of the area over the past thirty years. One hundred years ago most of the existing Blind Pass Area was non-existent. Over the past century this area has been constantly changing; the shoreline has shifted, accreting then eroding. "The 'loss' of sand into inlets is at most a temporary thing, and even then only where there are 'new' inlets, which do not yet have tidal deltas, does this become a major process. Any sediment that is trapped in the inlet itself is ultimately moved either in or out into the tidal delta storage bins. Since the ebb currents are generally the dominant inlet force, most sand moving into an inlet will ultimately be deposited in the offshore ebb delta. The shape of the ebb delta and the sediment movement within the delta is then strongly controlled by the interaction of the ebb and flood currents with the offshore wave system and the longshore currents. The sand stored in the ebb delta is now available for littoral transport onto the downdrift beach system. Also, high energy storms and floods flush out the inlet and move the sand laterally to be used to absorb the storm energy in the adjacent forebeach areas. Thus an inlet system plays an important role in sediment storage for use as an energy sponge during storms and has built-in sediment bypass mechanisms. Consequently, inlet systems represent an integral part of the overall sediment budget of the coastal system and contribute to the overall natural ability of the system to roll with the energy punches with minimal adverse effects. Modification and/or stabilization of an inlet will limit or eliminate this ability, increasing the potential for accelerated shoreline erosion resulting from major storms."[1]

All standards for the Gulf Beach Ridge Zone should be applied here with several further restrictions on changing or developing this area. Permanent human settlement in this high hazard area should be restricted to very low density or prohibited if possible. Any activity which would result in the alteration of or interference with inlet dynamics and Island building functions in this area should be prohibited. The precise boundaries of this area should be determined by a detailed geological survey.

Mid-Island Ridges Zone

This zone comprises the major ridges along the central axis of the Island and includes the highest topographic elevations. In most areas this zone divides the Bay-Mangrove watershed from the Interior Wetlands watershed. Like the Gulf Beach Ridge, this zone is also important in providing storm and flood protection, in recharging the fresh water aquifer, and in preventing degradation of water quality. This zone is the most tolerant for urban development with the application of regulations set forth in Article 3 of the Plan to protect crucial health, safety and welfare functions. Excavation which results in lowering the elevation of the ridge or in penetration of the aquiclude is prohibited. Storm runoff from paved or developed areas is to be retarded and dispersed slowly to the natural hydrologic system. Natural drainage channels are not to be disrupted or altered. The use

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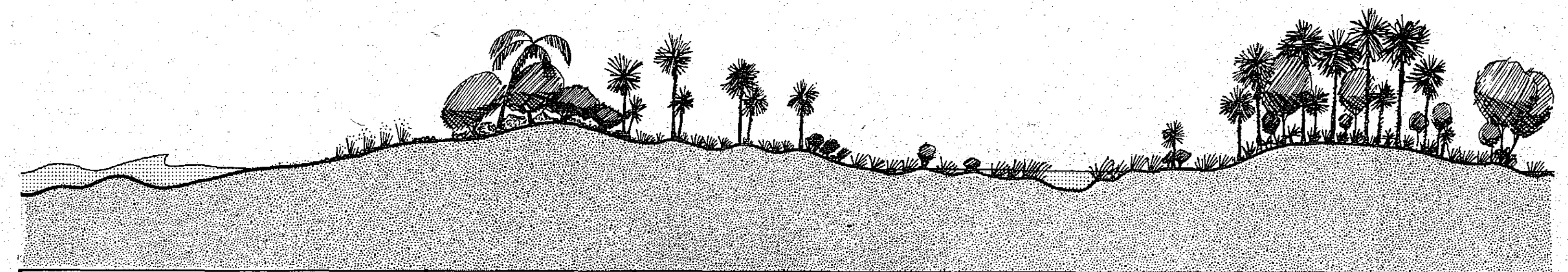
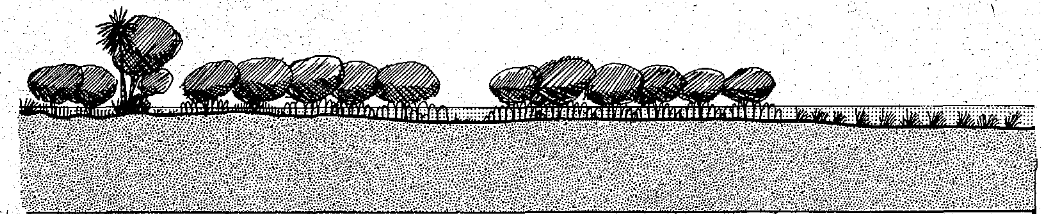
[1]Stanley R. Riggs, Geology of the Natural Beach System, Sanibel Island, Florida 1975.

[2]Duane Hall and Associates, 1975, cited in J.B. Morrill and W.K. Byle, Jr., "Preliminary Survey of the Marine Ecosystem Surrounding Sanibel Island," 1975.

[1]Stanley Riggs, op. cit.



GULF BEACH (FRONT BEACH / BACK BEACH)	GULF BEACH RIDGE	INTERIOR WETLAND BASIN (UPLAND / LOWLAND / UPLAND)	MID-ISLAND RIDGES
The Gulf Beach Zone includes the area between the state setback line and the city boundary 300' offshore. There are two subareas within this zone—the Front Beach and the Back Beach. The Front Beach extends from the city limit to Mean High Water. Sand in this subarea is in constant motion. Sand migrates between the berm and offshore bars and is transported by long-shore currents. The Back Beach comprises that area between Mean High Water and the the state setback line. Sand in this subarea is moved by wind and water and stabilized by vegetation, forming low dunes.	The Gulf Beach Ridge Zone is the major ridge immediately behind the beach. It is stabilized by dense vegetation. Blind Pass—a subarea within this zone—is of very recent formation and susceptible to dramatic change.	The Interior Wetland Basin Zone is the interior bowl which serves as a fresh water reservoir. It is composed of parallel systems of ridges and swales with corresponding bands of vegetation. There are two sub-areas within this zone – lowland and upland. The lowland area is composed of low ridges and wide swales and experiences extended periods of flooding each year. The upland consists of higher, broader ridges and narrower swales, and is characterized by less frequent flooding and more upland vegetation types.	The Mid-Island Ridges Zone comprises the major ridges along the central axis of the Island and includes the highest elevations. In most areas this zone divides the Bay-Mangrove watershed from the Interior Wetlands watershed.
CLIMATE Salt Spray	**CLIMATE**	**CLIMATE**	**CLIMATE** Salt Spray
GEOLOGY Oxidized barrier sands and shells	**GEOLOGY**	**GEOLOGY**	**GEOLOGY**
SUBSURFACE HYDROLOGY Saline Shallow Aquifer	**SUBSURFACE HYDROLOGY** Fresh Water Table Aquifer	**SUBSURFACE HYDROLOGY**	**SUBSURFACE HYDROLOGY** Fresh Water Table Aquifer
SURFACE HYDROLOGY Mean High Water 10 Year Storm Flooding 10 Year Storm Flooding 25 Year Storm Flooding	**SURFACE HYDROLOGY**	**SURFACE HYDROLOGY** Seasonal High Water Table at Surface Seasonally Flooded 10 Year Storm Flooding	**SURFACE HYDROLOGY** Seasonally Flooded 10 Year Storm Flooding
SOILS Oxidized Barrier Sands and Shells	**SOILS** Thin Organics	**SOILS** Organics over Sand Marl	**SOILS** Thin Organics
VEGETATION Widely scattered herbaceous vegetation and shrubs. Sea Oats, railroad vine, sea spurges, beach plum, sea purslane, bay cedar, yucca, salt bush. Invasion of Australian Pine.	**VEGETATION** Sea grape, yucca, bay cedar, saltbush, marsh elder, cabbage palmetto, wax myrtle, coconut palm. Invasion of Australian Pine.	**VEGETATION** Vegetation varies according to elevation and water levels. Swales: Cordgrass, sawgrass, andropogon, water hyssop, buttonwood, cattails, spatterdock, hydrilla, chara, duckweed, wigeongrass. Low ridges: Marsh elder, leather fern, wax myrtle, cabbage palmetto. Invasion of Brazilian pepper and Australian Pine.	**VEGETATION** West Indian Flora, Cabbage palmetto, saw palmetto, seagrape, gumbo limbo, Jamaica dogwood, Florida privat, wild lime, strangler fig, wild coffee, myrsine, joewood, wax myrtle, sea oxeye, poison ivy, Virginia creeper, prickly pear cactus, bowstring hemp, century plant. Invasion of Australian Pine, Brazilian pepper, and cajeput.
WILDLIFE Loggerhead Turtle, Bottle-nosed Dolphin, Otter, Manatee, Brown Pelican, Snowy Egret, Red-breasted Merganser, American Oystercatcher, Semipalmated Plover, Piping Plover, Snowy Plover, Wilson's Plover, Black-bellied Plover, Ruddy Turnstone, Willet, Knot, Least Sandpiper, Dunlin, Semipalmated Sandpiper, Western Sandpiper, Sanderling, Herring Gulf, Ringbilled Gull, Laughing Gull, Forster's Tern, Least Tern, Royal Tern, Sandwich Tern, Caspian Tern, Black Skimmer.	**WILDLIFE** Box Turtle, Gopher Tortoise, Green Anole, Key West Anole, Five-lined Skink, Six-lined Racerunner, Mangrove Watersnake, Black Racer, Indigo Snake, Coral Snake, Southern Toad, Green Treefrog, Squirrel Treefrog, Bobwhite, Smooth-billed Ani, Red-bellied Woodpecker, Great Crested Flycatcher, Purple Martin, Fish Crow, Starling, White-eyed Vireo, Prairie Warbler, House Sparrow, Cardinal.	**WILDLIFE** American Alligator, Box Turtle, Chicken Turtle, Soft Shell Turtle, Green Anole, Key West Anole, Five-lined Skink, Florida Watersnake, Ribbon Snake, Southern Toad, Green Treefrog, Squirrel Treefrog, Southern Leopard Frog, Pig Frog, Opossum, Armadillo, Marsh Rabbit, Sanibel Rice Rat, Sanibel Cotton Rat, Raccoon, Otter, Florida Bobcat, Pied-billed Grebe, Anhinga, Least Bittern, Mottled Duck, Blue-winged Teal, King Rail, Virginia Rail, Sora, Common Gallinule, Killdeer, Spotted Sandpiper, Common Snipe, Belted Kingfisher, Long-billed Marsh Wren, Swamp Sparrow.	**WILDLIFE** Gopher Tortoise, Green Anole, Key West Anole, Five-lined Skink, Six-lined Racerunner, Black Racer, Indigo Snake, Coral Snake, Diamondback Rattlesnake, Southern Toad, Green Treefrog, Squirrel Treefrog, Opossum, Armadillo, Marsh Rabbit, Sanibel Rice Rat, Sanibel Cotton Rat, Florida Panther, Florida Bobcat, Bobwhite, Smooth-villed Ani, Red-bellied Woodpecker, Great Crested Flycatcher, Purple Martin, Fish Crow, Starling, White-eyed Vireo, Prairie Warbler, House Sparrow, Cardinal.



MANGROVES			BAY BEACH
MANGROVES	TIDAL FLATS	MANGROVES	

MANGROVES

The Mangrove Zone includes all areas of red, black and white mangroves, as well as the tidal flats and hardwood hammocks within them. Much of this zone, including all areas of red mangrove, is subject to daily tidal flooding. Other areas of the zone are subject to extended periods of flooding every year.

CLIMATE

GEOLOGY

Oxidized Barrier Sands and Shells

SUBSURFACE HYDROLOGY

SURFACE HYDROLOGY

Mean High Water

SOILS

Peat Deposits Salt Flats

VEGETATION

Mostly mangroves with hardwoods at higher elevations. Vegetation responds to elevation and tidal patterns. Red mangroves predominate to the mean high tide line, black mangroves predominate to slightly higher elevations above the mean high tide line.

Red mangrove, black mangrove, white mangrove, buttonwood. Seagrape, gumbo limbo, palmetto

WILDLIFE

American Alligator, Green Anole, Mangrove Watersnake, Marsh Rabbit, Otter, Florida Panther, Manatree, Bottle-nosed Dolphin, Brown Pelican, Double-crested Cormorant, Great Blue Heron, Green Heron, Snowy Egret, Louisiana Heron, Little Blue Heron, Black-crowned Night Heron, Yellow-crowned Night Heron, White Ibis, Roseate Spoonbill, Lesser Scaup Duck, Red-breasted Merganser, Bald Eagle, Osprey, Clapper Rail, American Oystercatcher, Piping Plover, Snowy Plover, Wilson's Plover, Blackbellied Plover, Ruddy Turnstone, Eastern Willet, Laughing Gull, Least Tern, Black Skimmer.

BAY BEACH

The Bay Beach Zone extends from the city's boundary 300' into the bay to a setback line approximately 100' behind the Mean High Water Line. It is a lower energy beach than the Gulf Beach, and includes areas of marine grasses on the bay bottom. It includes both sand beach and mud beach.

CLIMATE

GEOLOGY

Muds, Organic Materials, Sands and Shells

SUBSURFACE HYDROLOGY

Saline Shallow Aquifer

SURFACE HYDROLOGY

10 Year Storm Flooding

25 Year Storm Flooding

SOILS

Muds, Organic Materials, Sands and Shells

VEGETATION

Sand beach: Sea oats, railroad vine, sea spurges, beach plum, sea purslane, bay cedar, yucca, salt bush. Invasion of Australian Pine

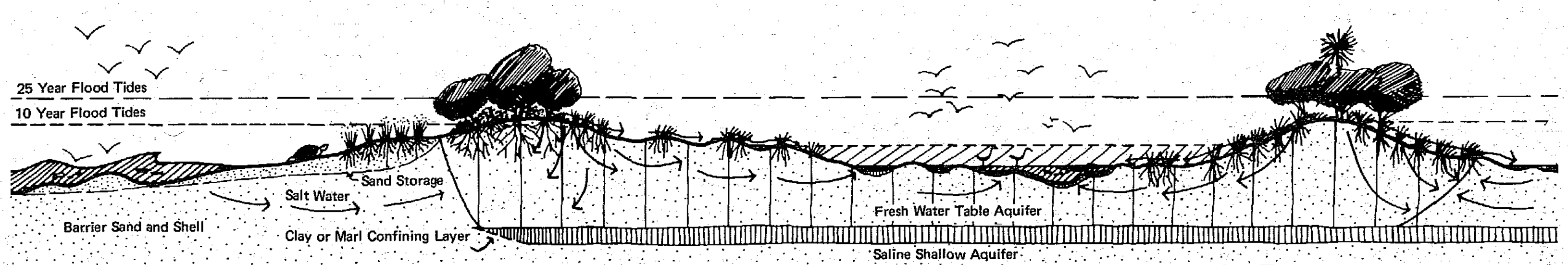
Mud beach: Red mangroves

Submerged beach: Marine grasses

WILDLIFE

Loggerhead Turtle, Bottle-nosed Dolphin, Otter, Manatee, Brown Pelican, Snowy Egret, Red-breasted Merganser, American Oystercatcher, Semipalmated Plover, Piping Plover, Snowy Plover, Wilson's Plover, Black-bellied Plover, Ruddy Turnstone, Willet, Knot, Least Sandpiper, Dunlin, Semipalmated Sandpiper, Western Sandpiper, Sanderling, Herring Gull, Ringbilled Gull, Laughing Gull, Forster's Tern, Least Tern, Royal Tern, Sandwich Tern, Caspian Tern, Black Skimmer.

ECOLOGICAL ZONES: INVENTORY



GULF BEACH

FRONT BEACH | BACK BEACH

The Gulf Beach Zone includes the area between the state setback line and the city boundary 300′ offshore. There are two subareas within this zone—the Front Beach and the Back Beach. The Front Beach extends from the city limit to Mean High Water. Sand in this subarea is in constant motion. Sand migrates between the berm and offshore bars and is transported by longshore currents. The Back Beach comprises that area between Mean High Water and the state setback line. Sand in this subarea is moved by wind and water and stabilized by vegetation, forming low dunes.

FUNCTIONS
Storm Protection
Shoreline Stabilization
Maintenance of Marine Life
Maintenance of Wildlife

The Gulf Beach Zone is the Island's first defense in storm and flood when the impact of storm waves erodes the sand reservoir in the berm. The low dunes of the Back Beach are a reservoir of sand which may be eroded after the berm in a severe storm, thus protecting property further inland on the Beach Ridge. The natural profile of the Gulf Beach Zone is a response to processes of wind, currents, and waves. Undistrubed, it is in a state of balance with natural forces, thus "stabilizing" the shoreline. The Front Beach supports the marine life for which Sanibel is famous, and is an important feeding area for island wildlife. The low dunes of the Back Beach are an important nesting area for wildlife, the loggerhead turtle being a prime example.

ELEMENTS ESSENTIAL TO FUNCTIONS

Storm Protection and Shoreline Stabilization:
—Natural profile of beach
—Sand reservoir in berm, bars and dunes
—Gradual and dispersed runoff from land
—Longshore sand movement
—Hardy dune vegetation

Maintenance of Marine Life
—Access to beach
—Good water quality

Maintenance of Island Wildlife
—Access to beach
—Good water quality
—Abundant marine life

GULF BEACH RIDGE

The Gulf Beach Ridge Zone is the major ridge immediately behind the beach. It is stabilized by dense vegetation. Blind Pass—a subarea within this zone—is of very recent formation and susceptible to dramatic change.

FUNCTIONS
Storm Protection
Flood Protection
Shoreline Stabliization
Maintenance of Water Quality
Maintenance of Fresh Water System

The Gulf Beach Ridge is a dike which buffers flood tides and storm winds, prevents increased flooding in the interior (unless overtopped by waves) and contributes to shoreline stabilization. Water quality is maintained by the filtering function of soil and vegetation. Much fresh water runoff enters the ground in the Gulf Beach Ridge Zone, halting inward intrusion of salt water from the Gulf and thus maintaining the extent of the fresh water lens.

ELEMENTS ESSENTIAL TO FUNCTIONS

Storm Protection and Shoreline Stabilization:
—Shoreline stabilization and storm protection functions of the Gulf Beach Zone
—Natural configuration and elevation of ridge
—well established hardy vegetation

Maintenance of Water Quality
—Gradual and dispersed runoff
—Filtration of runoff through vegetation and soil

Maintenance of Fresh Water System:
—Recharge of runoff to fresh water lens
—Drainage of runoff to interior wetland
—Aquiclude between shallow saline aquifer and fresh water lens.

INTERIOR WETLAND BASIN

UPLAND | LOWLAND | UPLAND

The Interior Wetland Basin Zone is the interior bowl which serves as a fresh water reservoir. It is composed of parallel systems of ridges and swales with corresponding bands of vegetation. There are two sub-areas within this zone—lowland and upland. The lowland area is composed of low ridges and wide swales and experiences extended periods of flooding each year. The upland consists of higher, broader ridges and narrower swales, and is characterized by less frequent flooding and more upland vegetation types.

FUNCTIONS
Flood Protection
Maintenance of Water Quality
Maintenance of Fresh Water System
Maintenance of Island Wildlife

Since the elevation of the Interior Wetland Basin is lower than the adjacent zones, it serves as a storage area for flood waters until they are absorbed into the aquifer. Water Quality is protected by the filtering function of soil and vegetation. This zone is crucial to the maintenance of the fresh water lens. It also has the capacity to maintain and improve water quality, and provides food, shelter, water, and nesting areas to wildlife, including the American alligator.

ELEMENTS ESSENTIAL TO FUNCTIONS

Flood Protection:
—Water storage capacity
—Free-flowing water circulation

Maintenance of Water Quality
—Free-flowing water circulation
—Gradual and dispersed runoff
—Filtration of runoff through vegetation and soil
—Restriction of industrial and domestic wastes discharged into interior wetland
—Water quality function of Gulf Beach Ridge and Mid-Island Ridges Zones

Maintenance of Fresh Water System:
—Recharge of runoff to fresh water lens
—Sufficient water levels
—Aquiclude between shallow saline aquifer and fresh water lens
—Free-flowing water circulation

Maintenance of Wildlife:
—Good water quality
—Fresh water system
—Access to water
—Native vegetation of value to wildlife

MID-ISLAND RIDGES

The Mid-Island Ridges Zone comprises the major ridges along the central axis of the Island and includes the highest elevations. In most areas this zone divides the Bay-Mangrove watershed from the Interior Wetlands watershed.

FUNCTIONS
Storm Protection
Flood Protection
Maintenance of Water Quality
Maintenance of Fresh Water System

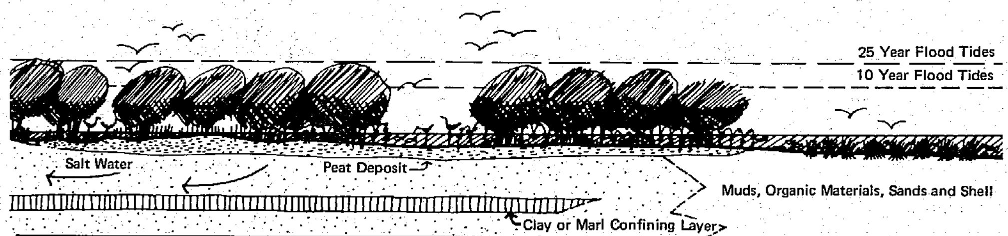
The elevation of the Mid-Island Ridges Zone provides flood protection. This zone helps maintain water quality by the filtering functions of soil and vegetation. Much fresh water runoff enters the ground in the Mid-Island Ridges Zone, halting inward intrusion of salt water from the Bay and thus maintaining the fresh water lens.

ELEMENTS ESSENTIAL TO FUNCTIONS

Flood Protection:
—Elevation of ridge

Maintenance of Water Quality:
—Gradual and dispersed runoff
—Filtration of runoff through vegetation and soil

Maintenance of Fresh Water System:
—Recharge of runoff to fresh water lens
—Drainage of runoff to interior wetland
—Aquiclude between shallow saline aquifer and fresh water lens
—Elevation of ridges



MANGROVES

MANGROVES	TIDAL FLATS	MANGROVES

The Mangrove Zone includes all areas of red, black and white mangroves, as well as the tidal flats and hardwood hammocks within them. Much of this zone, including all areas of red mangrove, is subject to daily tidal flooding. Other areas of the zone are subject to extended periods of flooding every year.

FUNCTIONS
Storm Protection
Flood Protection
Shoreline Stabilization
Maintenance of Water Quality
Maintenance of Marine Life
Maintenance of Wildlife

The dense canopy and roots of the mangroves buffer storm winds and tidal surges. The arching prop-roots of the red mangrove and the roots of the black mangrove trap sediments and stabilize and extend the shoreline. Mangroves preserve water quality by filtering suspended material and assimilating dissolved nutrients. Mangroves maintain the highly productive marine ecosystem and provide food, shelter, and nesting areas for wildlife.

ELEMENTS ESSENTIAL TO FUNCTIONS

Storm Protection, Shoreline Stabilization and Land Building:
—Healthy mangroves

Maintenance of Water Quality:
—Healthy mangroves
—Restriction of domestic and industrial wastes discharged into Mangrove Zone
—Water circulation

Maintenance of Marine Life:
—Healthy mangroves
—Good water quality

Maintenance of Island Wildlife:
—Healthy mangroves
—Abundant marine life

BAY BEACH

The Bay Beach Zone extends from the city's boundary 300' into the bay to a setback line approximately 100' behind the Mean High Water Line. It is a lower energy beach than the Gulf Beach, and includes areas of marine grasses on the bay bottom. It includes both sand beach and mud beach.

FUNCTIONS
Storm Protection
Shoreline Stabilization
Maintenance of Marine Life
Mainteannce of Wildlife

The Bay Beach Zone buffers the impact of storm waves. The natural form of the Bay Beach is a response to natural processes of wind, currents, and waves. Undisturbed, it is in a state of balance with natural forces, thus "stabilizing" the shoreline. The Bay Beach is a feeding area for island wildlife. Beds of marine grasses in submerged portions of the beach are important nursery and feeding areas for marine life.

ELEMENTS ESSENTIAL TO FUNCTIONS

Storm Protection and Shoreline Stabilization:
—Natural profile of beach
—Gradual and dispersed runoff from land
—Longshore sand movement
—Hardy beach vegetation

Maintenance of Marine Life:
—Mangroves
—Marine grass beds
—Access to beach
—Good water quality

Maintenance of Wildlife:
—Access to beach
—Good water quality
—Abundant marine life

ECOLOGICAL ZONES: FUNCTIONS

GULF BEACH

FRONT BEACH | BACK BEACH

Management Guidelines

Storm Protection and Shoreline Stabilization

Maintain natural profile of beach bars, berm, and dunes:
- Prohibit removal of sediments from beach.
- Prohibit construction of any sort on Front Beach.
- Prohibit construction on Back Beach except to provide beach access.
- Restrict public beach access to elevated walkways over the Back Beach.

Maintain sand reservoir in bars, berm, and dunes:
- Prohibit removal of sediments from beach.

Maintain natural patterns of gradual and dispersed runoff from land:
- Restrict runoff from paved and developed areas onto beach.

Allow for longshore sand movement:
- Prohibit construction of groins or any other structures which inhibit or prevent sand movement.

Maintain hardy dune vegetation:
- Restrict public beach access to elevated walkways over the Back Beach.
- Prohibit clearance of hardy native vegetation.
- Replace Australian Pines on Back Beach with hardy native dune vegetation.

Maintenance of Marine Life and Wildlife

Maintain access to beach from water.
Maintain good water quality:
- Prohibit discharge of insufficiently treated domestic or industrial wastes.
- Restrict runoff from paved and developed areas onto beach.

GULF BEACH RIDGE

Mangement Guidelines

Storm and Flood Protection and Shoreline Stabilization

Maintain natural profile and elevation of ridge:
- Prohibit development which would lower existing elevation.

Maintain hardy native vegetation:
- Restrict clearance of existing native vegetation.
- Establish hardy native vegetation in areas which are not well vegetated.
- Replace Australian Pine with hardy native vegetation whenever possible

Maintain storm protection and shoreline stabilization functions of Gulf Beach:
- Restrict runoff from paved or developed areas from draining onto the Gulf Beach Zone.

Maintenance of Water Quality

Maintain gradual and dispersed runoff:
- Retard and disperse runoff from paved and developed areas.

Filter runoff from paved and developed areas through vegetation and soil:
- Limit cleared and impervious areas.

Maintenance of Fresh Water System

Maintain drainage to interior wetland:
- Restrict alteration of existing natural drainageways.

Maintain integrity of aquiclude between saline aquifer and fresh water lens:
- Prohibit excavation of aquiclude.

Maintain recharge of fresh water lens:
- Limit cleared and impervious areas.
- Retard runoff over porous soils.

INTERIOR WETLAND BASIN

UPLAND | LOWLAND | UPLAND

Management Guidelines

Flood Protection

Maintain water storage capacity of the Interior Wetland Basin:
- Prohibit development activities which would result in a reduction of freshwater storage capacity.

Maintain natural free-flowing patterns of water circulation:
- Do not impede or impound water flow.
- Improve the Sanibel River system to provide for a continuous free-flowing stream.

Maintenance of Water Quality

Maintain natural free-flowing patterns of water circulation:
- See guidelines above

Maintain natural patterns of gradual and dispersed runoff:
- Retard and disperse runoff from paved and developed areas

Filter runoff from paved and developed areas through vegetation and soil:
- Limit cleared area and impervious surfaces

Regulate quality of domestic and individual wastes discharged into Interior Wetland Basin:
- Provide that all released effluent be of water quality equal to that achieved by advanced treatment.

Maintenance of Fresh Water System

Maintain recharge of runoff to freshwater lens:
- Limit cleared area and impervious surfaces.
- Retard runoff over porous soils.

Maintain sufficient water levels to prevent salt water intrusion.
Maintain integrity of aquiclude between shallow saline aquifer and freshwater lens:
- Prohibit excavation of the aquiclude.

Maintain natural free-flowing patterns of water circulation:
- See guidelines above.

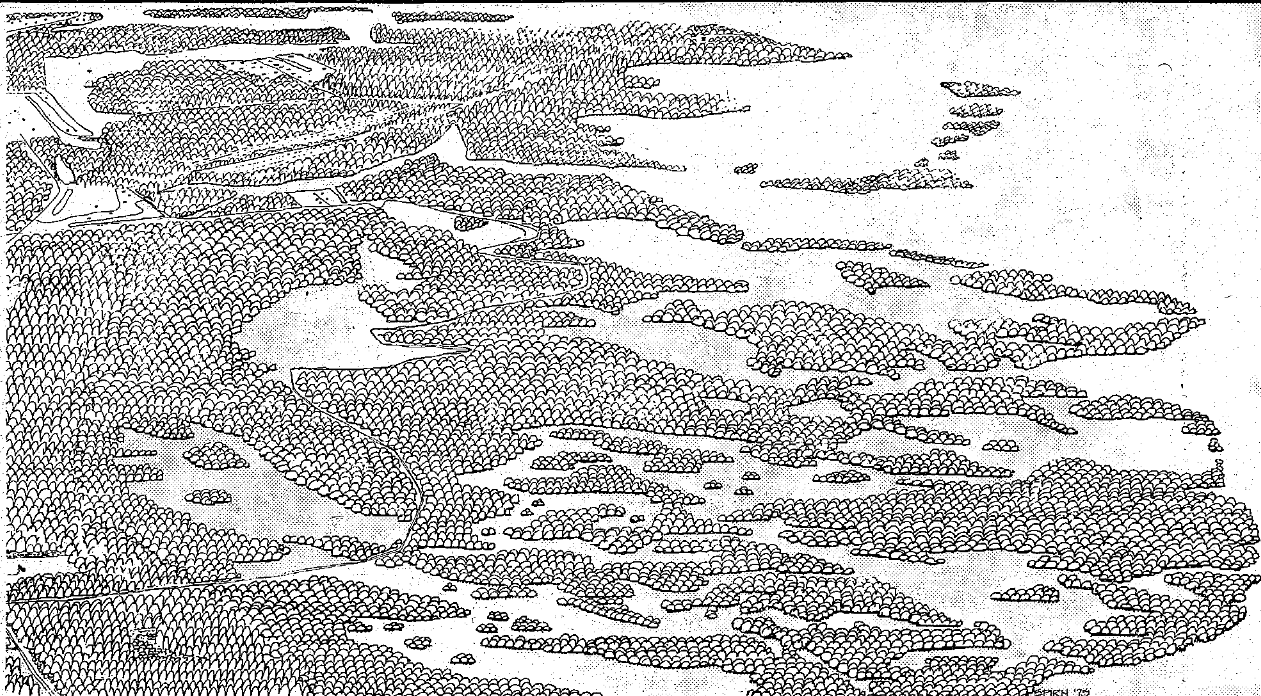
Maintenance of Island Wildlife

Maintain good water quality:
- See guidelines above.

Maintain fresh water system:
- See guidelines above.

Maintain wildlife access to water:
- Provide wildlife corridors connecting conservation areas with Sanibel Slough.
- Provide for wildlife movement along Sanibel Slough.

Maintain native vegetation of value to wildlife:
- Restrict clearance of vegetation valuable to wildlife.
- Remove exotic plant species which out compete or displace native species.



MID-ISLAND RIDGES

Management Guidelines

Flood Protection
Maintain existing elevation of ridge:
- Prohibit development activities which would result in lowering elevation of ridge.

Maintenance of Water Quality
Maintain gradual and dispersed runoff:
- Retard and disperse runoff from paved and developed areas.

Filter runoff from paved and developed areas through vegetation and soil:
- Limit amount of cleared area and impervious surface.
- Retard runoff over porous soils.

Maintenance of Fresh Water System
Maintain recharge of runoff to fresh water lens:
- Limit cleared area and impervious surfaces.
- Retard runoff over porous soils.

Maintain drainage of runoff to interior wetland:
- Restrict alteration of existing natural drainageways.

Maintain integrity of aquiclude between shallow saline aquifer and fresh water lens:
- Prohibit excavation of the aquiclude.

MANGROVES

MANGROVES | TIDAL FLATS | MANGROVES

Management Guidelines

Storm Protection Shoreline Stabilization, Land Building
Maintain healthy mangroves:
- Protect mangroves.
- Restrict excavation or filling.
- Maintain good water quality.

Maintain Water Quality
Maintain healthy mangroves:
- See guidelines above.

Regulate quality of domestic and industrial wastes discharged into Mangrove Zone:
- Provide that all water or other effluent which is released be of water quality equal to that achieved by advanced treatment prior to its release.

Maintain natural patterns of water circulation:
- Elevate roads and pathways so as not to impound or impede water flow.
- Maintain existing natural patterns of fresh water runoff from interior.

Maintain water quality function of Mid-Island Ridges Zone:
- Refer to guidelines for Mid–Island Ridges Zone.

Maintenance of Marine Life and Wildlife
Maintain healthy mangroves:
- See guidelines above.

Maintain water quality:
- See guidelines above.

BAY BEACH

Management Guidelines

Storm Protection and Shoreline Stabilization
Maintain natural profile of beach:
- Prohibit removal of sediments from beach.
- Prohibit construction on beach which would result in change of the natural beach profile.
- Restrict public access over vegetated areas of beach to elevated walkways.

Maintain natural patterns of gradual and dispersed runoff from land:
- Restrict runoff to beach from developed areas

Allow for longshore sand movement:
- Prohibit construction of groins or any other structures which inhibit sand movement.

Maintain hardy beach vegetation:
- Restrict public access over vegetated areas of beach to elevated walkways.
- Prohibit clearance of native beach vegetation
- Replace Australian Pines on the beach with hardy native vegetation.

Maintenance of Marine Life and Wildlife
Maintain existing mangroves on beach:
- See guidelines for Mangrove Zone.

Maintain marine grass beds:
- Maintain good water quality. (See below.)

Maintain wildlife and marine life access to beach:
- Prohibit construction on beach limiting access by wildlife or marine life

Maintain good water quality:
- Prohibit discharge of insufficiently treated domestic and industrial wastes.
- Prohibit runoff from paved and developed areas onto beach.
- Maintain water quality functions of Mid Island Ridges and Mangrove Zone.

ECOLOGICAL ZONES: MANAGEMENT GUIDELINES

of septic tanks, impervious paving, and the clearance of native vegetation is severely restricted.

Filled Land

This is a man-made zone, created artificially by disturbing the natural topography and vegetation of an area for real estate development purposes. In most cases the area delineated on the maps of Ecological Zones has been elevated to approximately five feet above mean sea level either by importing fill or by excavation within the site area. The purpose of such modifications to the landscape has been to transform low lying land that is often wet and unsuitable for development into high dry land associated in some cases with lakes, lagoons and canals formed by dredging below the water table.

For planning purposes, only the larger areas of filled lands were mapped, thereby excluding spoil areas from mosquito ditches and canals that did not cover extensive areas. Some of the areas have been filled for twenty years or more, so that grasses and woody plant materials have established. Other areas that are more recently filled are bare but for the invasion of scattered weeds.

Permitted land uses and development intensity for such development are described in 2.5.1 and 2.5.2 and regulated by Article 3 of the Comprehensive Plan.

DELINEATION OF ECOLOGICAL ZONES

In order to map the ecological zones, the planners depended heavily upon published sources available during the summer of 1975 and field studies. These included U.S.G.S. topographic mapping with five foot contour interval, aerial photographs, recommended coastal construction setback by the Department of Natural Resources, State of Florida, and studies by natural scientists for Sanibel-Captiva Conservation Foundation. The boundaries of the zones are shown on the Ecological Zones, Existing map. The City is undertaking a program to provide a one-foot topographic survey of the entire City and, upon its completion, will review and revise as appropriate all of the boundaries on a City-wide basis. Until that can be accomplished no evidence regarding potential shifting of zone boundaries should be accepted to avoid prejudicing rights of neighbors. Applications for permits received prior to the revision of the boundary lines but not decided prior to such revision, will be decided on the basis of the revised boundary lines.

Gulf Beach

The delineation of the Gulf Beach Zone is based upon setback recommendations by the State of Florida Department of Natural Resources presented to the City during 1975. The setback line was determined on the basis of beach profiles and shoreline dynamics and is intended to protect the beach zones from environmental degradation and construction. The Gulf Beach Zone is characterized by widely spaced non-woody plants and semishrubs. Sea spurge, sea purslane and sundrops are common perennials. Railroad vine occurs quite frequently, along with sea oats and grass. Beach plum, bay cedar, yucca and salt bush are shrub and semishrubs plants found along the beach stand. Australian pines have been naturalized and spread along the upper portions of the beach.

Bay Beach

The delineation of the Bay Beach Zone is based on a 50 foot setback from the Mean High Water Line along the Bay Shore. Detailed examination of beach profiles and shoreline dynamics similar to that conducted by the State along the Gulf Beach was not undertaken. However, since the Bay Beach is less dynamic than the Gulf Beach, which averages a 200 foot setback, a smaller setback was chosen. It is recommended that in the future the City of Sanibel conduct a survey using similar criteria to those employed by the State. Typical vegetation on the Bay Beach from Lighthouse Point to Woodring Point is the same as that found on the Gulf Beach. These include sea spurges, sea purslane, sundrops, railroad vine, yucca, salt bush and Australian pine.

Gulf Beach Ridge

The delineation of the Gulf Beach Ridge Zone is based upon studies by the Conservation Foundation -- "Environmental Habitats" map ("Beach Ridge") -- and on U.S.G.S. topographic survey which was used to delineate areas at or above five feet elevation. Some of the species characteristic of the beach stand are also characteristic of the ridge. These include: yucca, bay cedar, salt bush and a few of the herbaceous perennials. Also cabbage palm, sea grape, wax myrtle and the ubiquitous Australian pine can be found here.

Special Blind Pass

The delineation of the Special Blind Pass Zone is based on a study of shoreline changes in the Blind Pass area over the past 100 years (Duane Hall Associates, 1975). The Blind Pass area is adjacent to the Blind Pass Inlet most of which has been deposited or subject to major changes over the past 100 years.

The vegetation of this area is very much the same as that of the Gulf Beach Ridge, although there is much more Australian pine and only a small area of cabbage palm, sea grape, wax myrtle and marsh elder.

Mid-Island Ridge

The delineation of the Mid-Island Ridge Zone is based on the Conservation Foundation's "Environmental Habitats" map and on the U.S.G.S. topographic survey to delineate areas at or above five feet elevation.

Species of the West Indian flora and several introduced trees are characteristic of this area. Included in the desirable woody native category are cabbage palm, saw palmetto, gumbo limbo, sea grape, Jamaica dogwood, Florida privet, wild lime, strangler fig, wild coffee, myrsine, joewood, wax myrtle, bow string, hemp, century plants and air plants. Vines such as virginia creeper and poison ivy are common while several perennials can be found as well. Brazilian pepper, Australian pine and cajeput have invaded the ridge, frequently displacing the West Indian vegetation.

Interior Wetland: Lowland

The delineation of the Lowland Interior Wetland Zone is based primarily on that area of the interior identified as "wetland" by the 1975 Johnson Engineering study of the Sanibel Island Fresh Water Management area for the Sanibel-Captiva Conservation Foundation. This "wetland" area experiences a seasonal high water table at the ground surface or higher. Additional areas of lowland interior wetland were identified by natural scientists in their 1975 studies for the Conservation Foundation and identified in their "Environmental Habitats" map. The low swales in the wetlands are vegetated with cordgrass, saw grass, sea purslane and buttonwood frequently invaded by Brazilian pepper.

Interior Wetland: Upland

The delineation of the Upland Interior Wetland Zone is based on the Conservation Foundation's "Environmental Habitats" map and is subject to occasional high water table and flooding and is generally less than five feet elevation. On slightly higher and drier ground, salt bush, marsh elder, leather fern, wax myrtle and cabbage palm grow. Chara spp, Hydrilla spp, duckweed and wigeon grass are aquatic plants associated with inland pools and canals. Brazilian pepper has successfully invaded both the lowland and upland while Australian pine is confined to the slightly higher shell ridges.

Mangroves

The delineation of the Mangrove Zone is based on the map of mangrove areas provided by Conservation Foundation consultants. This map was refined by reference to a 1" = 800' aerial photograph flown in the summer of 1975. This zone includes all areas of buttonwood, red, black and white mangroves. A few woody and non-woody species occur in conjunction with red, black and white mangroves. Air plants and orchids grow epiphytically while sea oxeye is common and wax myrtle and bay cedar occur sporadically in the understory.

It is apparent from the preceding descriptions of ecological zones that some zones are more tolerant of development than others. The charts describing Ecological Zones (2.3.1-3(a)(b)(c) summarize the conditions; hazards; guidelines for environmental management in all zones. It is clear that extensive areas of Sanibel are not suitable for urban development and that in most cases health, safety and welfare and environmental protection will only be achieved by strict adherence to the performance standards described in Article 3 of the Plan.

Filled Land

The delineation of Filled Land Zone is based upon aerial photographs; maps of Historical Ecological Zones by Conservation Foundation Studies[1], and field inspection by the planning consultants. Determination of these areas was on the basis of land that had apparently been disturbed by topographic change and clearing of vegetation for real estate development purposes. Only those areas where such activities were apparent over a large area and achieved an elevation of approximately five feet above mean sea level were included. Several categories of filled land exist within these areas including some which have variations in topography, vegetation, and water bodies.

B. PLAN FOR THE PRESERVATION OF ECOLOGICAL FUNCTIONS RELATING TO HEALTH, SAFETY AND WELFARE

The plan for the preservation of the ecological functions of the Island of Sanibel is provided for through the adoption of the development regulations and performance standards set forth in Article 3 of the Plan. A map identifying the various ecological zones is officially adopted along with specific standards for development, based on the ability of each ecological zone to tolerate such future development.

1"Sanibel National Systems Study" by John Clark, Project Director, The Conservation Foundation.

Section 2.3.2: Coastal Zone Protection †

Section 2.3.3: Wetland Protection

A. BACKGROUND DISCUSSION †

B. THE HYDROLOGY †

C. VEGETATION †

D. WILDLIFE †

E. WATER LEVEL

The wetlands serve as an integral part of this Island's natural system, without which its whole ecology would suffer. The key to their health rests in establishing an appropriate water level and protecting water quality. A water level (equal to the level of the "hard pan" under buttonwood ridges as suggested by Tabb and Roessler) would allow year-round populations of insects to thrive while permitting native marsh vegetation to prosper.

Water quality will be improved by the controls, and improved flow in the Sanibel River will prevent most of the present salt water intrusion and allow flushing of that which may accumulate. The prevention of salt water pollution of the interior will enhance wildlife habitats and increase the utility of the fresh water lens.

The reduction of salt water contamination in the river will sustain fresh water vegetation and associated animal species, which include the anhinga, bitterns, rails, many more bird species, the river otter, bass, bluegill and others too numerous to list. All these would be eliminated if the fresh water system were to be lost to a salt water system.

However, high elevations for control structures should be investigated since, at abnormally high tides and low interior water levels, the salt water overtops the structures. Intruding salt water flows inland as a density current, and spreads throughout the existing stream channel, in some cases entering ponds or other water bodies. Under drought conditions, fresh water level sometimes drops below mean sea level, permitting seepage of salt water into the ground water system. The salt intrusions can, if permitted to continue, cause a marked change in the ecosystem of the Island.

An appropriate balance must be achieved between the management requirements of the interior wetlands and the safety of the Island residents. It is possible that a water level of about 3.0 feet could possibly be maintained if more control structures and outflow barriers were installed. Missimer[1] suggests that setting the water stage at 3.0 feet at the existing control structure would not be adequate to achieve the 3.0 feet level throughout the wetland and that the water level would have to be controlled in steps.

Therefore once the water table is initially adjusted to 2.5 feet above msl, some of the major problems now evident in Sanibel will be automatically ameliorated. It is likely, however, that specific action will have to be taken to eradicate as completely as possible the Brazilian pepper. Most other introduced plants may disappear with a change in water level.

It is likely that more detailed technical study for water management will find that the most practical solution is a system that has fixed structures at different elevations. Under natural conditions the elevation of standing water varies greatly; however, in the absence of good topographic surveys, these recommendations cannot be specific regarding elevations.

F. PLAN FOR WETLAND PROTECTION

In order to establish the most suitable water level, more detailed topographic and engineering studies must be done. Fixing the now movable control structures at Tarpon Bay and Beach Road at their existing elevation of 2.5' will only partially achieve the desired result. However, fixing these structures at a higher elevation without further study would threaten existing roads and buildings with flooding on the Island

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[1]Missimer, "Sanibel Island: Hydrology",1975, Prepared for the Conservation Foundation,Inc.

during higher intensity storms. Until the plan for storm drainage in the interior wetland is implemented (see Section 2.2.6) this drainage will also have several important benefits in terms of wetland management.

It is also imperative that the River, the ditches, the ponds, and lakes be freed from any sewage pollution. These water bodies are now largely eutrophic showing low levels of oxygen at depth and wide fluctuations at the surface. The cause (and remedy) for this is not immediately apparent. Obviously it is due to the organic materials reaching the water (whether from pollution, natural plant decay, fertilizers or other). In any event, this should be studied and appropriate remedial action taken (such as dredging out deposits, etc.) The filling-in with undesirable vegetation is an inescapable outcome of high-nutrient levels; this is now evident in scattered places along the River where algae bloom can be seen. Not only is this unsightly vegetation, but it has negligible value for wildlife.

Section 2.3.4: Wildlife Preservation

A. BACKGROUND DISCUSSION †
B. BIRDS †
C. REPTILES AND AMPHIBIANS †
D. MAMMALS †
E. MARINE LIFE †
F. CONCLUSION

Unfortunately the fauna of a small land area almost always suffer as human population increases. It is an objective of the Plan to indicate a way to lessen this negative stress. Basically an attitude of benign co-existence with wild creatures must be wholeheartedly accepted by the public. Attitudes are unlegislatable but, with positive education such as that undertaken by Sanibel-Captiva Conservation Foundation, great strides can be made.
Each wildlife group has its own requirements and tolerances. Marine biota is sensitive to excessive sedimentation, toxicity and nutrient pollution and changes in configuration and vegetation in their nesting and sanctuary areas. Over-harvesting of fish and live shells is, of course, a quick way to extermination. High speed power boats pollute the waters, and can directly harm some species and disrupt the marine environment in general. Larger mammals co-exist poorly with humans because they need sizeable undisturbed areas in which to roam, where hiding places are abundant and where smaller prey exist. If these requirements are met, the thrill of seeing a bobcat or panther in the wild could remain a possibility on Sanibel.

Birds co-exist well with man as long as their food source is plentiful and uncontaminated, and they have private areas for nesting and raising their young. Unfortunately, this has not been the case with reptiles and amphibians which have been deliberately sought and exterminated. Snakes are sensitive to human intrusion, many being very secretive and less adaptable to environmental modifications than warm-blooded creatures. Next to deliberate killing of these creatures, habitat destruction has been a major cause of their decline. Most lizards, snakes, turtles and crocodilians have very specific water demands though somewhat less specific food requirements.

Regulations which would set the tone of a sanctuary island can be legislated. Lowered speed limits, speed bumps and speed rumbles, would decrease the chance of roadkills; areas cordoned off would allow for non-interrupted nesting; maintenance of every historical habitat would allow for all species to have a place to live; improvement of habitat through encouragement of native vegetation would give desirable species the best chance while rigorous monitoring should inhibit pollution of its air and waters.

G. THE PLAN FOR WILDLIFE PRESERVATION

The City should give further consideration to enacting regulations which would encourage the preservation of the Island's natural wildlife and would set the tone of a sanctuary island.

Swamps - Wetlands

Buttonwood - *Conocarpus erecta*
Red mangrove - *Rhizophora mangle*
Black mangrove - *Avicenni nitida*
White mangrove - *Laguncularia racemosa*
Endangered

Muhly grass - *Muhlenbergia capillaris*
Varnish leaf - *Dodonaea viscosa*
Christmas berry - *Lycium caroliranum*
Molina - *Maytenus phyllanthoides*

Stands

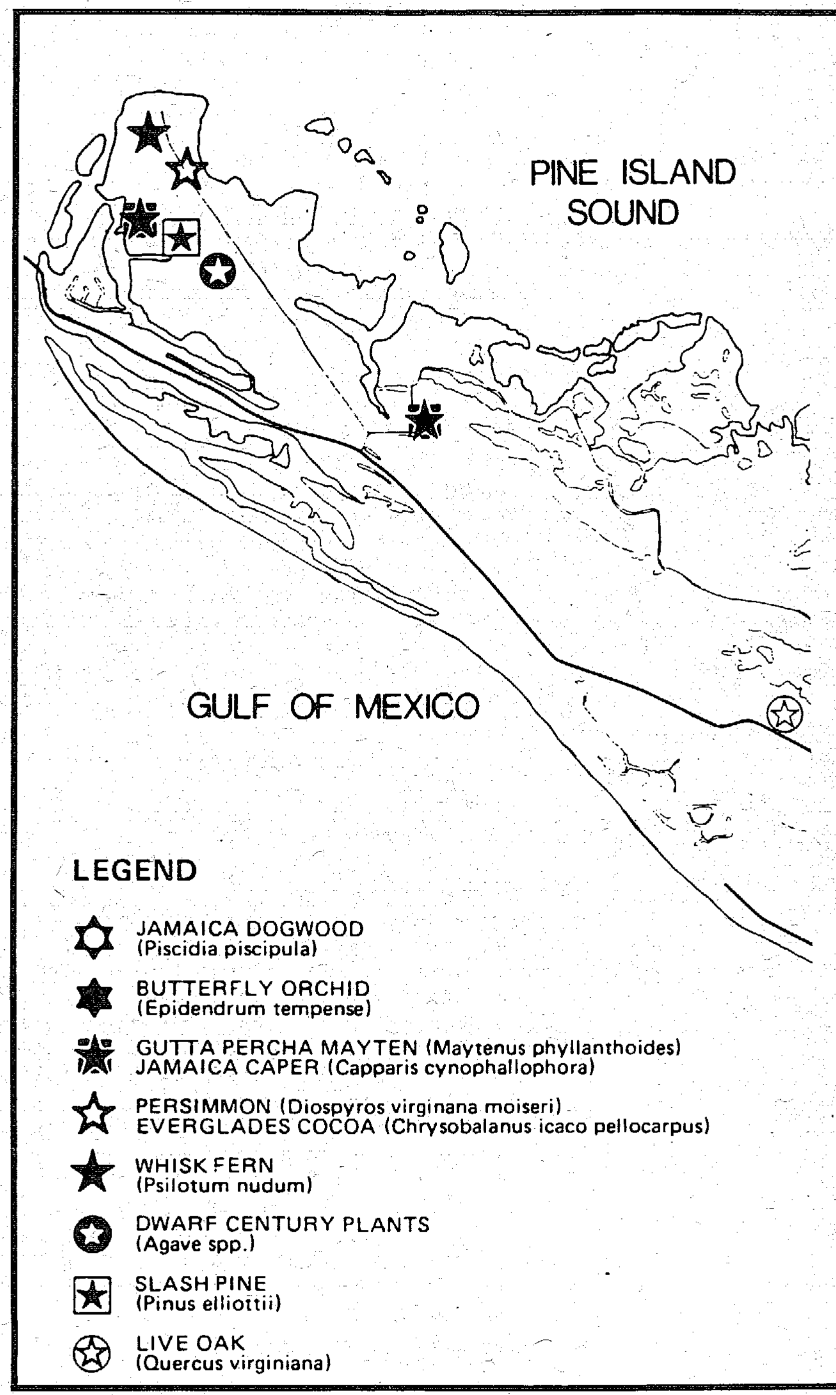
Slash pine - *Pinus elliottii*
Live oak - *Quercus virginiana*

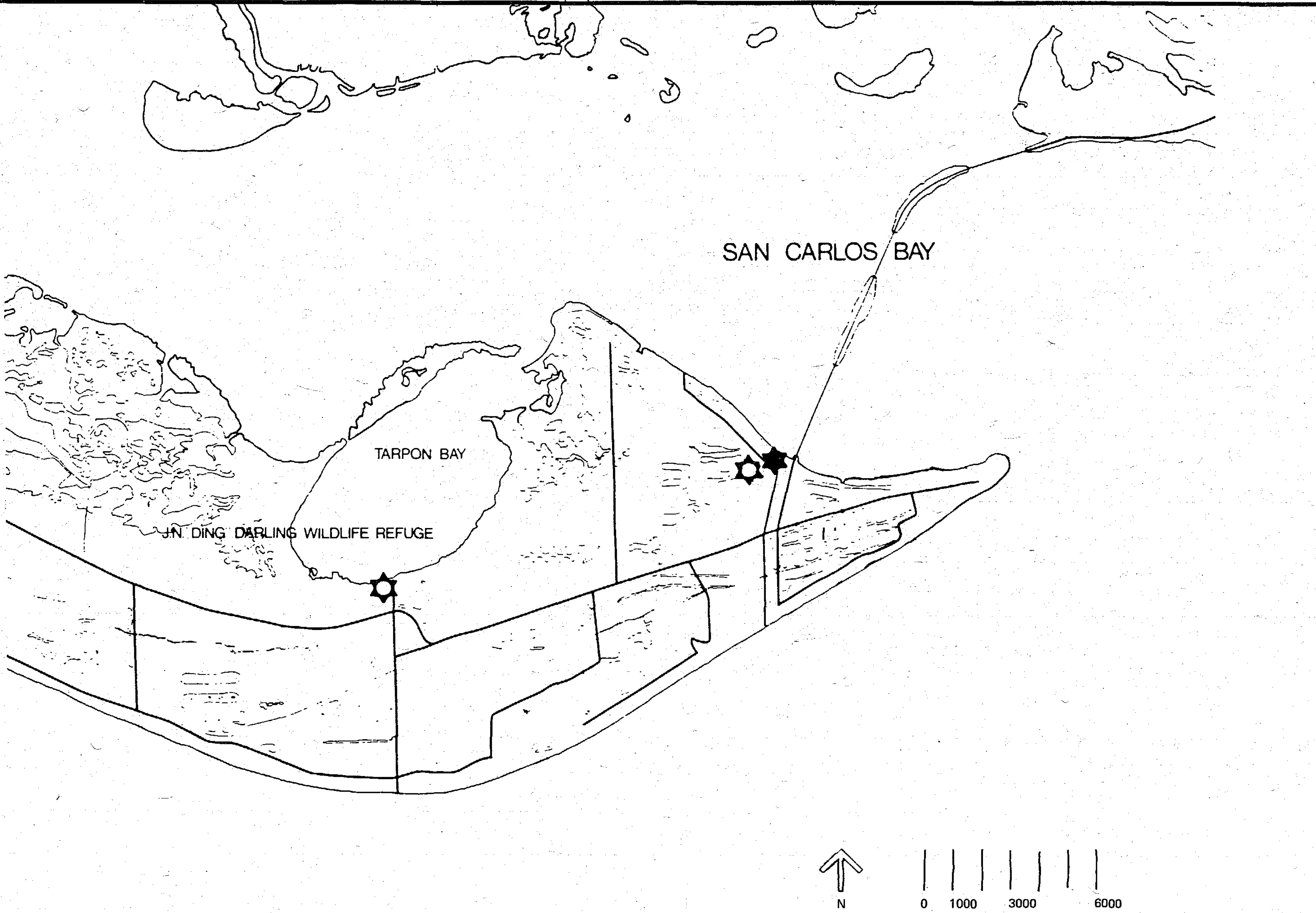
Exotics Which Should Be Discouraged on Sanibel

Australian pine - *Casuarina equisetifolia*
Casuarina cunninghamiaria
Brazilian pepper - *Schinus terebinthifolius*
Cajeput - *Melaleuca quinquenervia*
+Guava - *Psidium guajava*
+Bowstring hemp - *Sansevieria thyrsiflora*
+Life Plant - *Bryophyllum pinnatum* &
related species
Vitex trifolia
Wedelia trilobata

As an additional measure for achieving maximum ecological preservation of vegetative values, the City should develop a program for replacing with more beneficial vegetation all undesirable species of plant, including Australian pines, the Brazilian pepper and the melaleuca tree from City-owned land, and encourage other levels of government with land ownership and private individuals on Sanibel to do the same.

+ Do not present a problem if controlled.





Source: Harvey Roberts and Richard Workman, 1975

EXCEPTIONAL VEGETATION

Section 2.3.5: Vegetation Preservation

A. BACKGROUND DISCUSSION †

B. THE PLAN FOR VEGETATION PRESERVATION

In order to protect the vegetation values identified in this section, it is necessary that the City of Sanibel:

1) Prohibit the introduction of exotic species of plant which tend to outcompete or otherwise displace native species of plant;

2) Encourage the removal of undesirable exotics currently existent on the Island;

3) Limit clearing of native vegetation;

4) Protect valuable native species of plant from destruction; and

5) Encourage the use of native species of plant in the landscaping of future developments.

To achieve those ends, performance standards are set out in Article 3 of this Plan which set forth certain restrictions on the development of land in regard to exotic and native species of plant. However, the standard and criteria for development activity are not sufficient to achieve Island-wide protection of vegetation values. Therefore, the vegetation committee, as created by City Ordinance, should be responsible for encouraging sound ecological management of vegetative resources in those portions of the City for which future development is not proposed. That Committee should be an advisory body responsible for collection, analysis, and dissemination of information on basic ecological principles as they relate to Island vegetation. The Committee should, in addition, make available to the best of its ability expert assistance for any person on the Island who desires help with the clearing or landscaping for a development activity. Such assistance may include but not be limited to the identification of plant individuals that should be preserved, arrangements for the transplanting of appropriate individuals to other parcels on the Island, and the location of appropriate native species of plant for landscaping. Among the species of plant which the committee may encourage the preservation of are:

PLANTS WHICH SHOULD BE PROTECTED:

Beaches

Sea oats - _Uniola panicularा_
Railroad vine - _Ipomoea pes-caprae_
Sea purslane - _Sesuvium portulacastrum_
Bay cedar - _Suriana maritima_
Beach madder - _Ernodea littoralis_
Beach plum - _Scaevola plumieri_

Dunes

Joe-wood - _Jacquinia keyensis_
Sea grape - _Coccolobis uvifera_
Necklace pod - _Sophora tomentosa_

Ridge

Red stopper - _Eugenia axillaris_
White stopper - _E. rhombea_
Coco plum - _Chrysobalanus icaco pellocarpus_
Jamaica caper - _Capparis cynophallophora_
Coral bean - _Erythrina_
Strangler fig - _Ficus aurea_
Gumbo limbo - _Bursera simarouba_
Snowberry - _Chiococca alba_
Mastic - _Mastichodendron foetidissum_
Catclaw - _Pithecellobium keyense_
Jamaica dogwood - _Piscidia piscipula_
White indigo berry - _Randia aculeata_
Joe-wood - _Jacquinia Keyensis_
Saw Palmetto - _Serenoa repens_
Butterfly orchids - _Epidendrum tampense_
Tillandsia spp. except Spanish Moss
Whisk fern - _Psilotum nudum_

Interior Wetlands

Cordgrass - _Spartina bakerii_
Sawgrass - _Cladium jamaicense_

Section 2.3.6: Historic Preservation †

Section 2.3.7: Scenic Preservation

A. BACKGROUND DISCUSSION

Sanibel Island is renowned for the natural beauty of its gulf beaches and subtropical landscape. These are important economic as well as aesthetic resources for both residents and visitors. Sanibel's reputation as a unique retreat of unspoiled beauty continues to attract more residents and tourists annually. The parts of the Island experienced by most visitors and residents are most subject to degradation and therefore require some measure of protection and regulation. These are the beaches and the wildlife refuge, and the major roadways that provide access to them.

The beaches in the East and East Central Sectors of the Island are to some degree impacted by large condominiums which are constructed close to the beach with no visual screen. As a result, these are no longer the "unspoiled" beaches which have long attracted visitors to Sanibel. However, at the western end of the Island and in some areas of single family homes on the eastern end, single family houses are set back sufficiently from the beach and surrounded by dense vegetation so that they do not impair the scenic values of the beach. In this way the "natural" character of the shoreline is preserved for all to enjoy, resident and visitor alike.

A beach setback and buffer of dense vegetation should be employed in any new development near the beach whatever the density or land use. In addition to the scenic impact, storm protection is enhanced by such a strategy. It also benefits marine and wildlife that use the beach for nesting and feeding. Restriction of building heights to 45 feet above mean sea level is also important with respect to scenic preservation of the beach zones as are several other regulations proposed for conservation of the coastal environment. Scenic preservation of the J. N. "Ding" Darling Wildlife Refuge is within the aegis of the U. S. Federal Government. To date this has been accomplished with no negative impact on the Island. It is most important that the Sanibel-Captiva Conservation Foundation exercise maximum control of scenic resources in its several land holdings in mangrove and wetland areas so that these are enjoyed in their natural state by visitors.

The other major vantage for the Island's scenic resources is that of the major roadways which give access to all environments and land uses. These roads generally follow the Island's two natural ridges and are connected by several roads which cross the interior. Periwinkle Way, Gulf Drive, and the Sanibel-Captiva Road, are the City's main collector streets and commercial arteries with fairly high traffic volumes.

Most Island businesses are located along Periwinkle Way and many of the Island's tourist accommodations are on Gulf Drive. Land along the Sanibel-Captiva Road is relatively undeveloped except for the Blind Pass commercial area and scattered residential subdivisions. The variety of visual experience along these roads today is due to the alteration of man-made environment and the natural landscape. This pattern of intermittent commercial development separated by stretches of dense trees and shrubs close to the road gives a casual atmosphere to even the busiest roads.

In order to preserve the casual scenic quality, future commercial uses should be concentrated in pockets along the road, separated by recreational and residential uses in much the same manner as they are today. Existing trees or plants in the road right-of-way should not be removed except where they are a traffic or storm hazard, are a nuisance, or where necessitated by street improvements. If removal of trees becomes necessary, provision should be made for replacement with approved plant species. Vegetation buffers should be established to preserve scenic quality even as further development or road improvements occur. Such buffers can also accommodate bicycle and pedestrian paths. In commercial areas, curb cuts should be kept to a minimum and shell should be used in parking lots instead of impervious paving such as asphalt. These standards will contribute to the preservation of the "casual" retreat atmosphere and serve safety and storm drainage purposes simultaneously Signs for commercial establishments should be clearly legible, and integrated with the vegetation buffer. Neon and flashing signs should be prohibited in all areas.

Three major cross-Island routes, Casa Ybel Road, Tarpon Bay Road and Rabbit Road, provide a totally different experience of the Island's various natural landscapes. These roads cross through the heavily treed upland interior wetlands to the grassy lowland interior wetland and the Sanibel Slough, to the Gulf Beach Ridge and Gulf Drive. Vegetation buffers should be established, and residential uses should be concentrated in upland areas where houses can be screened by trees.

These standards for maintaining scenic quality are consistent with other objectives of the Comprehensive Land Use Plan, and are in many cases, also recommended for other reasons such as storm protection, traffic safety, and water quality maintenance. The adoption of specific standards for regulation of scenic preservation will allow Sanibel to accommodate more urban growth while preserving the beauty of its natural areas and roadways.

B. THE PLAN FOR SCENIC PRESERVATION

The following are the general policies for scenic preservation and are implemented in Article 3 of the Plan:

1. Vegetated buffers should be established where feasible along the Gulf and Bay Beaches up to a setback line.

2. Encourage dense vegetation within the beach buffer to screen development behind the setback line. Use hardy native plant species such as seagrape which can withstand storm winds.

3. Establish vegetated buffer strips on major roadways. These buffers should include space for ornamental planting, bicycle and pedestrian circulation.

4. Concentrate future commercial uses on Periwinkle Way and Sanibel-Captiva Road in pockets, rather than spreading them out in a continuous strip.
5. Encourage the use of shell surfacing for parking areas to maintain a casual retreat atmosphere.

6. Integrate signs with the roadway buffers.

7. Prohibit neon signs and flashing signs.

Part 2.4: Intergovernmental Coordination†

Part 2.5: Land Use

Section 2.5.1: Permitted Uses

A. BACKGROUND DISCUSSION

The use of land and buildings in the City of Sanibel should be determined by the capacity of natural and man-made environments to accommodate such uses without hazard to health, safety and welfare of the citizens and visitors to the City. The determination of permitted uses also should take into account existing patterns of development and the need to maintain compatibility with existing uses as far as possible.

Historically the Island has developed as a residential community catering to a fairly wide income range with diverse dwelling types and small commercial and service establishments that serve both the resident and tourist population and also provide employment. In recent years there has been a significant increase in the proportion and number of condominium apartments, most of which are rented for a portion of the year. Also, as a consequence of rapid growth since 1970, new commercial establishments have developed giving rise to shopping centers and "strip commercial" development. These land use trends have generally utilized land more intensively than in the past and as a consequence greatly modified the natural environment. Traffic congestion, increased storm water runoff, beach erosion, air and water pollution and other negative impacts have resulted from such intensive land uses and the visual character of the Island has changed dramatically.

The Comprehensive Plan provides that the type and intensity of future land uses permitted shall be determined by the capacity of the Island to accommodate further development in an orderly manner with minimum negative impact. In addition to these overall considerations, environmental factors intrinsic to each ecological zone, compatibility with existing land uses, availability of adequate human support systems and compatibility with all elements of the Plan influenced the choice of permitted uses and development intensity. Regulations pertaining to permitted uses are described in 3.2.1 thru 8. development intensity is described in 2.5.2.

The general principles on which the use regulations are based are as follows. In the Gulf Beach Ecological Zone, permitted uses should be restricted to recreation and conservation uses that will not cause degradation of the natural environment, because this zone is a fragile and dynamic system providing protection from storms, habitat for wildlife and recreational amenity for people. In the Gulf Beach Ridge, recreation and conservation uses are encouraged, and single family detached, attached, and multifamily residential and resort housing and accessory uses are permitted. This zone is landward of the beach environment by virtue of a setback and is generally on land having an elevation of at least five feet above mean sea level. It can accommodate various land uses provided that they are in moderate or low intensity and that standards for site modification and building construction are designed to protect the natural environment and all property. It is the policy of the Plan not to permit further intensive urban development in this ecological zone and that open space should be preserved to maximum degree feasible. For these reasons on the Gulf Beach Ridge moderate residential densities are permitted along with accessory uses, selected on the basis of compatibility with existing land uses and current or prospective availability of human support systems such as utilities and traffic access.

The Special Blind Pass area is not currently developed as intensively as the eastern sections of the Island, nor does it have the same level of human support systems. In addition to recreation and conservation land uses, low intensity residential uses are permitted, and commercial use is permitted at one designated area near the Blind Pass Bridge.

The Interior Wetlands include two ecological zones. The uplands are the elevated ridges of the wetlands that are generally not wet but are subject to occasional high water table and flooding. The lowlands are subject to seasonal high water table and generally wet, having plant materials and wildlife associated with wetland ecology. In the Wetland Uplands, recreation, conservation, horticulture, agriculture and low intensity residential uses are permitted. Also commercial uses in designated areas, education facilities and public facilities. In the Wetland Lowlands recreation, conservation, horticulture, and low intensity residential uses are permitted.

The Mid-Island Ridge Ecological Zone comprises the major ridge along the center of the Island and includes the highest elevations. This factor plus its distance from both the Gulf and the Bay, make it a relatively protected location for development; also the natural environment is the least fragile and dynamic of any on the Island. Roads and other human support systems are either in existence or planned for the Mid-Island Ridge, and the historic pattern of development is that of mixed land uses at moderate and low densities. Low intensity residential uses are permitted. Also commercial, restricted commercial, public facilities including government offices, schools and utilities along with recreation and conservation are permitted.

The Mangrove Forest Ecological Zone comprises all areas having substantial growth of buttonwood, red, black and white mangroves. Such areas are generally low lying and wet, and provide rich habitat for wildlife performing diverse and important ecological functions. Land use permitted in the Mangrove Forest Zone are low intensity residential, recreation and conservation.

The Bay Beach Ecological Zone is also an active beach zone, extending along the Island's Bay Shore line and delineated by a 50 foot setback from the mean high water line at the shore. Permitted uses are restricted to boat docks, marinas, recreation, and conservation.

The Filled Land Ecological Zone has been created artificially by disturbing natural topography and vegetation for real estate development. The areas delineated on the map of Ecological Zones include the major area on the Island where such disturbance has taken place, are generally at five feet elevation, and have had the majority of natural vegetation removed. Permitted uses in the Filled Land Ecological Zone are moderate and low intensity residential; Commercial and Restricted Commercial in designated areas; public facilities including government offices, schools, utility and recreation facilities.

The Comprehensive Plan provides for the above permitted uses to be developed in the respective ecological zones subject to development intensities specified in 2.5.2 and the provisions of Article 3.

B. THE PLAN FOR PERMITTED USES

This section of the Plan discusses the general principles from which future permitted uses are derived, and it is the intent of the Plan to permit the continuation of all existing uses. The regulations controlling permitted uses are set forth in Article 3 of the Plan.

PERMITTED USE
- by ECOLOGICAL ZONE -

Gulf Beach
- .Recreation & Conservation
- .Elevated Walkways

Bay Beach
- .Recreation & Conservation
- .Boat Docks & Marinas

Mangroves
- .Recreation & Conservation
- .Residential
  - .Single Family Detached

Wetland Lowlands
- .Recreation & Conservation
- .Public Facilities
- .Agriculture
- .Residential
  - .Single Family Detached

Wetland Uplands
- .Recreation & Conservation
- .Public Facilities
- .Educational Facilities
- .Commercial*
- .Restricted Commercial*
- .Residential
  - .Single Family Detached
  - .Duplex

Special Blind Pass
- .Recreation & Conservation
- .Public Facilities (beach oriented)
- .Commercial*
- .Residential
  - .Single Family Detached
  - .Duplex

Gulf Beach Ridge
- .Recreation & Conservation
- .Public Facilities (beach oriented)
- .Commercial**
- .Residential
  - .Single Family Detached
  - .Duplex
  - .Multi-family
  - .Resort Housing (in areas having a 3.0 or greater Development Intensity)

Mid Island Ridge
- .Recreation & Conservation
- .Agriculture
- .Public Facilities
- .Commercial*
- .Restricted Commercial*
- .Residential
  - .Single Family Detached
  - .Duplex
  - .Multi-family

Filled Land
- .Recreation & Conservation
- .Agriculture
- .Public Facilities
- .Commercial*
- .Restricted Commercial*
- .Residential
  - .Single Family Detached
  - .Duplex
  - .Multi Family
  - .Resort Housing (in areas having a 5.0 Development Intensity)

* in areas designated on the Permitted Uses map
** as an accessory use to the Resort Housing

Section 2.5.2: Residential Development Intensity

A. BACKGROUND DISCUSSION

The constraints imposed by hurricane safety, water supply and sewage disposal demonstrate general principles clearly that unlimited future population growth would be hazardous to health, safety and welfare of the public. To minimize these hazards it is essential to limit the total number of dwelling units (including hotel and motel units, trailer spaces, condominiums, duplexes and single family homes) to between six and seven thousand. This will represent a growth of over 50% from the 4000 units established to exist in 1975.

If the dwelling units are kept within this range the water consumption and sewage generation can probably be handled in a manner consistent with the public health, safety and welfare, based on present knowledge. Further data could, of course, indicate a need to reduce or increase these limits. Moreover, by keeping the number of persons using the Island to these levels, it should be possible with careful planning to safeguard the lives of the people on Sanibel and Captiva in case of all but the most extreme hurricanes.

To allocate roughly 2000 new units throughout the City, the factors which determine the appropriateness of various residential intensities were analyzed including municipal economy, physical land capability, and service capability. Using an allocation formula (described in the Appendix to the March 1976 draft of the CLUP) tentative density allocation was prepared.

The formula took into account the relative proximity of all areas to existing human support systems and to the ecological zones. Policies were developed that future growth should be directed to areas where services are available and that environmentally valuable or hazardous areas should have proportionally less growth. The formula also took into account capital investments already made to prepare land for development and the degree to which a project or subdivision was improved and built out. The result of this process allocated 2000 dwellings across the Island in densities ranging from one dwelling per thirty-three acres to three dwellings per one acre depending upon the location, ecological zone and the extent of improvement to the land. Once the units were allocated under the formula the Planning Commission made adjustments taking into account consideration of existing development patterns and the extent to which existing subdivisions and projects are consistent with the goals, objectives, and policies of the Comprehensive Plan. In some cases adjustments were made to ensure that the density allocation would not permit higher densities than would be consistent with the character of existing residential areas.

No development is permitted in the beach setback zones but these areas were allocated a residential density, all of which must be built landward of the setback line.

All of the adjustments had the aggregate effect that allocated densities ranged from one dwelling per thirty three acres to five per acre and possibility for 3,580 additional dwellings under 100% build out conditions. A more realistic projection is that approximately two-thirds of this number will in fact be built during the effective period of the Plan. On this basis the Comprehensive Plan is based upon 6000-6500 total dwelling units in the future.

B. PLAN FOR RESIDENTIAL DEVELOPMENT INTENSITY

The distribution of residential development intensity shall be in accordance with the density allocation on the Development Intensity Map at City Hall (the Development Intensity Map in this section is a representation of the official Development Intensity Map and is provided in this Plan for informational purposes only.

Section 2.5.3: Housing†

Section 2.5.4: Commercial Development

A. BACKGROUND DISCUSSION

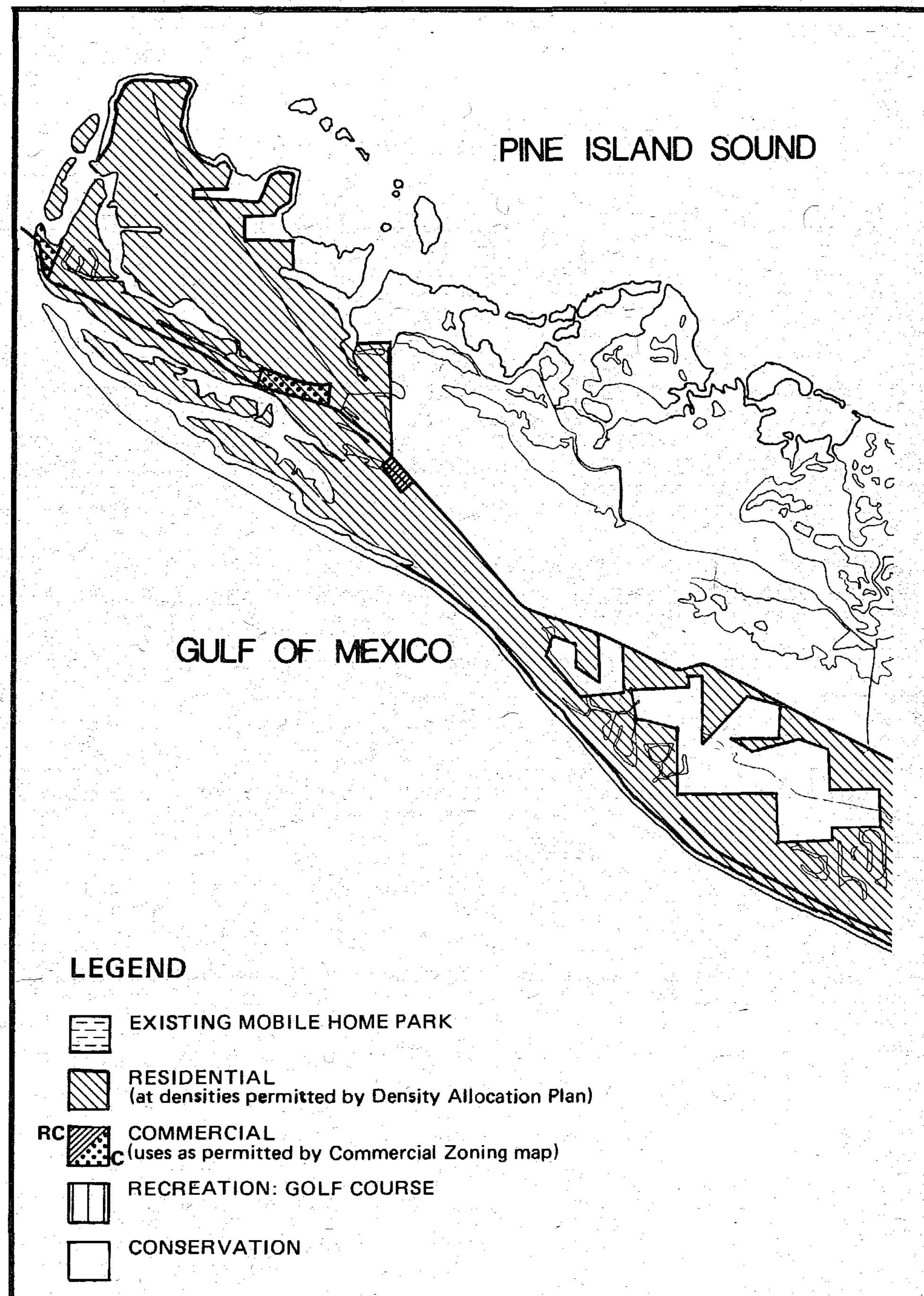
In the course of evaluating the desirability of various types of commercial development for the City of Sanibel studies were undertaken of the commercial land use patterns of other cities of a size similar to Sanibel, but it became apparent that the existing experience of other communities was not a logical pattern on which to base the plan for Sanibel for a number of reasons:

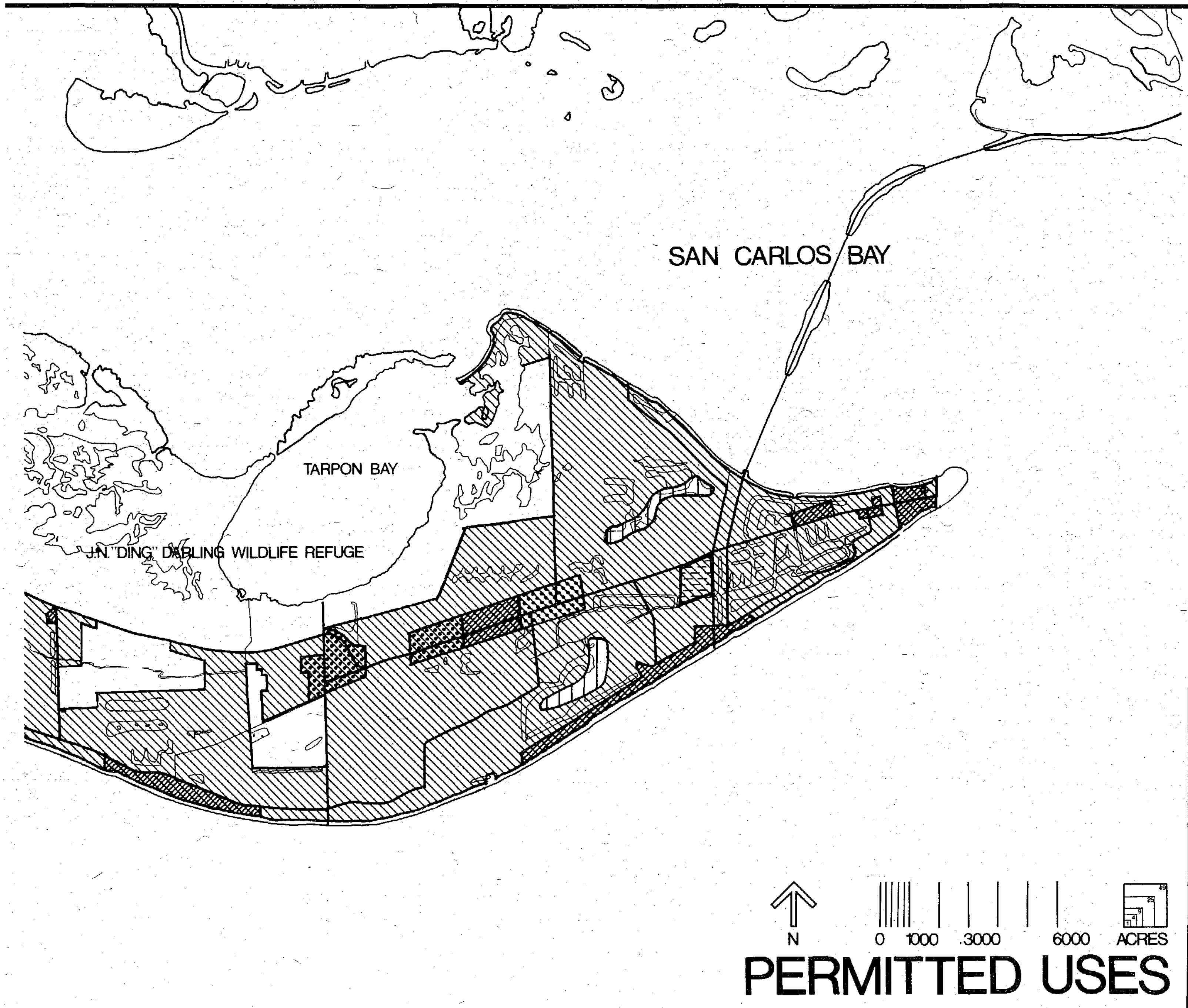
1. Unlike most communities Sanibel is located at the end of a long, dead-end road and therefore attracts almost no casual travellers passing through on their way elsewhere. Thus Sanibel needs fewer of the typical roadside type of commercial use than most communities its size.

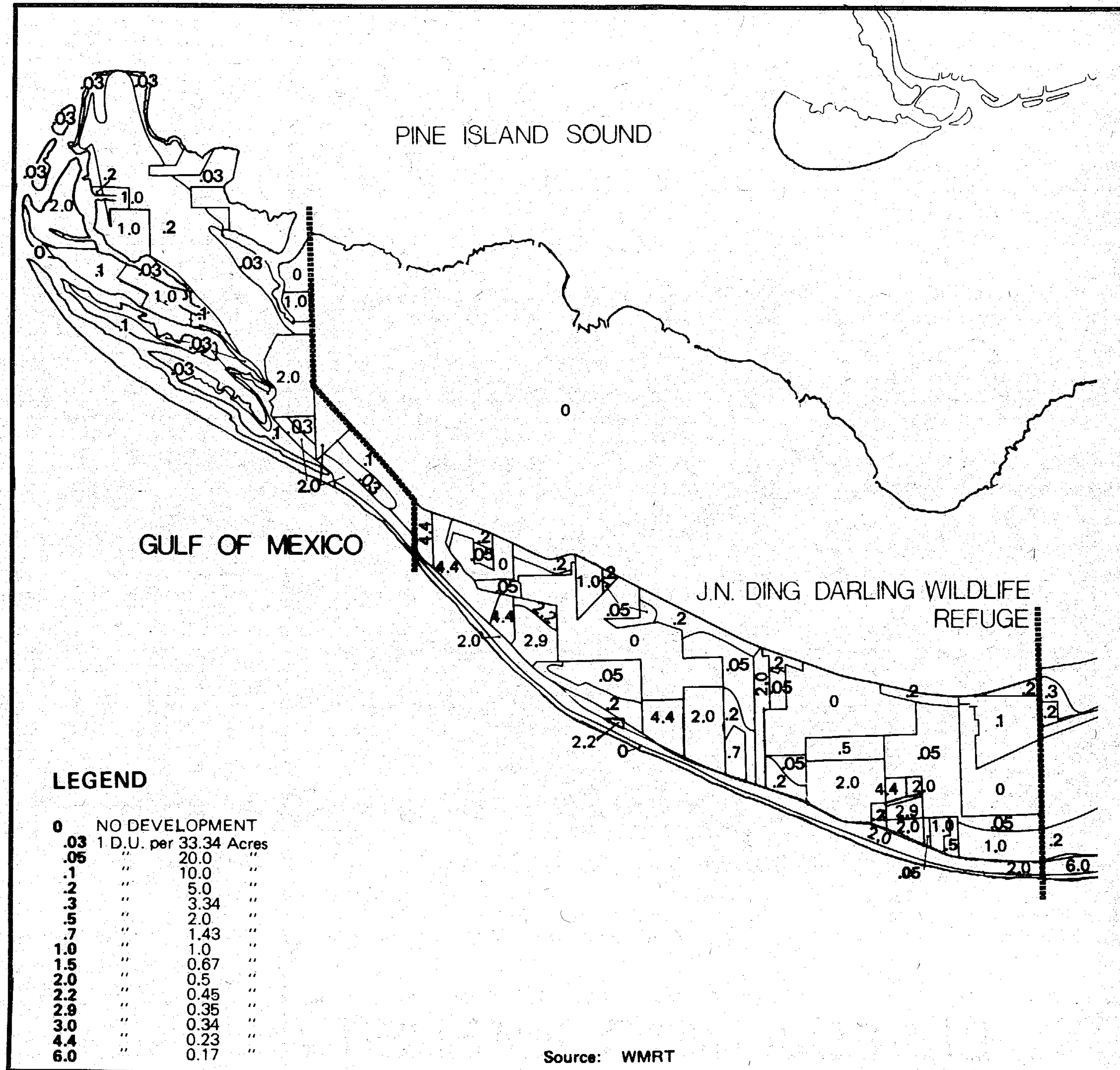
2. Sanibel attracts a unique blend of tourists with special interests (e.g. shell collectors, fishermen, tennis players, etc.). Because no other community attracts a similar mix of tourists, no other community provides a pattern on which commercial land uses can be based.

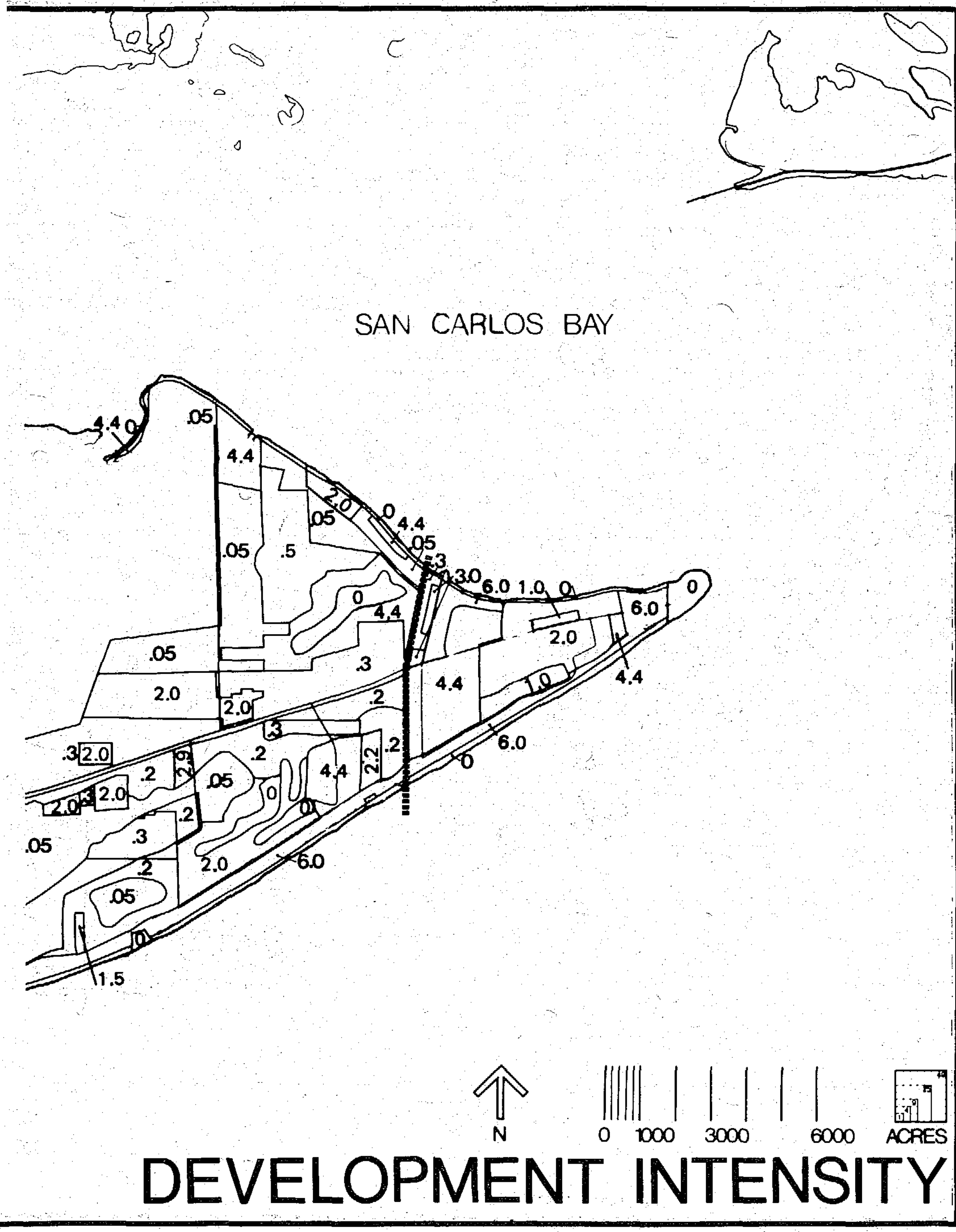
3. Residential accommodations for tourists (which have often been included in the category of commercial land uses) are undergoing a rapid metamorphosis. The distinction between temporary accommodations for tourists and permanent residential accommodations is becoming blurred as condominiums offer short-term rentals and time sharing plans while traditional resorts add larger dwelling units and condominiums. Thus the past experience of any community may not be a useful guide to its future.

Given these unique circumstances of Sanibel and the rapid changes taking place in the tourism industry, it is difficult to make definitive, long-term projections about the need for various types of commercial uses in Sanibel. Therefore the City should proceed cautiously, allocating enough land to permit a limited number of additional commercial uses, but not overzoning large areas for commercial purposes.




SAN CARLOS BAY
TARPON BAY
J.N. "DING" DARLING WILDLIFE REFUGE
N
0 1000 3000 6000
ACRES
PERMITTED USES


PINE ISLAND SOUND
GULF OF MEXICO
J.N. DING DARLING WILDLIFE REFUGE
LEGEND
0 NO DEVELOPMENT
.03 1 D.U. per 33.34 Acres
.05 " 20.0 "
.1 " 10.0 "
.2 " 5.0 "
.3 " 3.34 "
.5 " 2.0 "
.7 " 1.43 "
1.0 " 1.0 "
1.5 " 0.67 "
2.0 " 0.5 "
2.2 " 0.45 "
2.9 " 0.35 "
3.0 " 0.34 "
4.4 " 0.23 "
6.0 " 0.17 "
Source: WMRT



Because of Sanibel's isolation and small size there is clearly no need for such commercial uses as warehousing, wholesaling or other uses serving a large region. As a result the plan for commercial land uses is restricted to retail/service uses and resort housing.

Retail and Service Uses

The majority of retail and service uses should be urged to concentrate in the Commercial districts shown on the Permitted Uses Map. Four such districts have been mapped around existing commercial clusters along Periwinkle Way running from Bailey Road to the center of the Island, and each contains substantial land available for additional commercial construction. One small commercial district has been placed at the west end of the Island to serve the shopping needs of the people of Captiva and the isolated residences in the western sector of the City.

To provide additional areas to meet the convenience shopping needs of Island residents, several zones for restricted commercial uses have been identified in areas that are accessible to residents, and small scale retail and service uses not located in shopping centers would be consistent with the ambience of the area. One such Restricted Commercial (RC) district has been mapped on the heavily developed eastern end of the Island. A second Restricted Commercial use is located at the eastern boundary of the mid-island Commercial area, in order to provide for a transitional area leading in to the major mid-island commercial area. Another small Restricted Commercial district has been so located to serve the needs of residents in the west central sector.

Restricted commercial districts permit most ordinary retail and office uses but impose a maximum floor area limitation of 1500 square feet for most sturctures. There is no such size limitation in the commercial district.

All of these districts in the aggregate provide sufficient land for the retail and service needs of the City for the near future.

Because of the unique nature of the City it is difficult to estimate such needs far in advance. If the failure rate of retail and service establishments increases it may be necessary to reduce the commercially zoned area. On the other hand, if a demand for more such uses is apparent then additional land could be added to the commercial districts.

Resort Housing

Another type of income-producing use in the City of Sanibel is resort housing. Prior to the construction of the Causeway such housing took the form of small fishing camps and beach resorts. The construction of the Causeway brought more and bigger beach resorts.

The late sixties saw a statewide boom in the construction of condominiums extending into the early 1970's.Lee County permitted the construction of numerous condominium complexes, some of which were constructed at locations dangerously close to the water and built at densities that detracted from the character of the Island as a desirable living environment.

By 1975 it was clear that a massive overbuilding of condominiums had taken place throughout the State. Despite special tax incentives some 70,000 condominium units remained unsold. A number of sizeable projects on Sanibel became insolvent and virtually unoccupied, creating problems of police and fire protection and tax delinquency.

Meanwhile, other condominium projects were moving more and more into the resort hotel business with widely advertised short term rentals.

These dramatic and rapid changes in the nature of the tourism business on Sanibel have had numerous adverse impacts on the environment. The entire character of the community as a low-density settlement compatible with the natural environment has been threatened. The unique environmental character of the island, which has provided the primary attraction for both tourists and permanent residents, is now in danger.

Nor is the option of converting the Island to an urbanized, high-density recreational community along the lines of Miami Beach worthy of serious consideration. The Island's isolation would make it a highly uneconomic competitor with heavily urbanized resort areas even on the unlikely assumption that the residents of the City someday choose that goal.

Clearly, then, the protection of the character and long range base of the tourism industry demands a significant reduction in the density of resort housing accommodations. The City has no desire to cater to tourists who prefer to vacation in a high-density urbanized type of environment.

Many other areas in this state willingly provide for and eagerly solicit the trade of such visitors. But Sanibel offers unique charms, for which some people will pay a premium while they exist--but if they are destroyed by overuse, the City will have little to offer.

For this reason resort housing has been identified primarily in the Gulf Beach Ridge areas and given a density of no less than 3.0 per acre which may be calculated to include land in the setback zone. These are the areas where such densities can most easily be accommodated consistent with the overall land use Plan.

Many of the finer beach resorts in Florida and throughout the world have been developed at low densities of five or six units per acre. Such densities permit the provision of amenities and services that will attract more selective tourists willing to pay a premium for Sanibel's special character.

Because of the changing nature of the tourism industry it is not easy to make distinctions between various types of resort housing at the present time. However, to encourage the construction of facilities having a unified ownership and operation, only such facilities are to be permitted to operate restaurants and shops as an accessory use. Access to such accessory uses must be provided from within the resort complex rather than from the street or public way.

B. PLAN FOR COMMERCIAL DEVELOPMENT

Commercial Development should occur in the areas delineated on the Permitted Use Map and will be regulated by the requirements set forth in Article 3.

Section 2.5.5: Institutions †

Section 2.5.6: Recreation and Open Space

A. BACKGROUND DISCUSSION

Federal, county, municipal, and private recreation facilities and open space exist on Sanibel. The Federally owned and administered areas -- J.N. "Ding" Darling Wildlife Refuge, Lighthouse Point, the Bailey Tract, and the Perry Tract -- attract thousands of visitors from all over the country. Other areas in public ownership include

Turner Beach and several picnic areas and beach access points, as well as the elementary school which has a baseball diamond, basketball courts, and a playground. Two private golf courses are planned and there are several private tennis courts and limited marina facilities open to the public for a fee. The Sanibel-Captiva Conservation Foundation owns extensive land in the interior wetland and maintains nature trails in one area.

For a City its size, Sanibel appears to have an abundance of certain types of recreation facilities and open space. However, many of these facilities are also used by the thousands of tourists who come to Sanibel each year and by day visitors who come primarily to the beach or to the J.N. "Ding" Darling Wildlife Refuge. Thus, despite miles of wide, white sandy beach and 3500 acres in the "Ding" Darling Refuge, Sanibel residents experience overcrowding of some recreation facilities during the peak tourist season. Degradation of the dunes and beach ridge and inadequate parking at beach access points, hazardous bicycle routes and insufficient facilities for youth are major problems of recreational deficiency on the Island today.

The major shortage of suitable facilities area is at the beach. Parking is inadequate and the dunes are eroded by constant foot traffic at the more heavily used access points. Parking for cars and bicycles, restrooms, bathhouses, and elevated walkway access to the beach should be provided at the major access points. The dunes and beach ridge and the dune and beach ridge vegetation should be restored. In order to limit the number of visitors to the beach areas so that overcrowding and degradation are minimized, adequate beach access is provided in several areas of the Island so as to disperse the beach usage over a wider area and reduce the overcrowding of specific locations.

Sanibel will always attract tourists to its famous beaches and other resources. This is a major impact on the Island and must be planned for so that the social and environmental values are protected and so that the commerce generated by such visits can be a benefit to the City and its residents.

Bicycle paths have been marked along selected Sanibel roads. These are presently very hazardous because there is insufficient space for bicycles on many roads which are presently carrying very high volumes of automobile traffic. Bicycle paths should be outside the pavement of all major streets and in the right-of-way within vegetation buffers.

Considerable interest has been expressed in a center for youth and in public recreation facilities for active sports such as baseball and football. These facilities should be centrally located. Recreation facilities should be associated either with an existing center such as the Community Building or the school, or with a new youth center. The Mid-Island Ridge Zone along Periwinkle Way is particularly well suited to intensive recreation uses. Although several options exist for public acquisition and improvement of land for active recreation, the Plan recommends a site in the middle of the Island as the preferred location.

The Youth Center is needed to cater to young people for organized groups such as scouts and other youth groups and for informal gatherings of individuals. This should be located where active fun and noise would not be distracting to the pleasure of others -- near Tarpon Bay at the west end. It could alternatively be related to the Community Center where the advantages of multipurpose indoor and outdoor space would allow such varied activities as dancing, arts and crafts, continuing education and informal relaxation. This is an urgent need if Sanibel is to be a community that caters to its young people.

Sanibel now has two marina facilities sufficient to dock approximately 52 boats. Boating is particularly popular in Florida and Sanibel offers uniquely fine recreational boating both in the Gulf and Bay. Fishing is exceptionally good and there is ample variety of choice for the pleasure boater who wishes the tranquility and solitude of being out on the water. In order to meet continued demand for boating facilities for the next increment of population growth on Sanibel, it is proposed that permits be granted for 50% additional boat slips and support facilities.

In the recreation plan, priority should be given to solving the problems of beach access and parking and to bicycle paths, since both these have important public safety elements. Secondly, planning for a youth center and public recreation facilities should be initiated and acquisition of land for these facilities considered.

Cost estimates for the Recreation Element are summarized as follows:

1. Parking provision for 1000 cars:

i - 10 lots approximately 1 acre each, land at $15,000/ac		$150,000
ii - grading and surfacing with shells, markers, etc. at $.50 per foot, 10 lots @ $20,000 each		200,000
Subtotal i:		$350,000

2. Shelters, restrooms and changing rooms:

i - 5 structures @ $20,000 each		100,000
ii - 5 access boardwalks to beach		25,000
Subtotal ii		$125,000

3. Active recreation park:

i - 4 tennis courts @ $8,000	$32,000
2 hard court areas	16,000
other play areas and equipment	22,000
ii - play fields, grading and equipment	50,000
iii - land cost	80,000
Subtotal iii:	$200,000
TOTAL:	$675,000

Costs for the Youth Center are not included in this estimate because of inadequate information regarding sites and program.

B. PLAN FOR RECREATION AND OPEN SPACE

1. Maintain existing recreation facilities.

2. Maintain and identify all existing beach access easements and restrict public access across private property except where such easements exist.

3. Provide parking at selected beach access points, also restrooms, bathhouses, bicycle parking, and an elevated walkway access to the beach.

4. Provide bicycle paths throughout the Island outside the pavement of major streets and in the right-of-way within the vegetation buffers. (see Section 2.2.2)

5. Restore dunes and beach ridges and dune and beach ridge vegetation in areas of erosion near the beach access points.

6. Explore further the needs and funding requirements for a youth center on Sanibel. Implement a planning program to provide this facility within five years.

7. Provide centrally located additional public recreation facilities for active sports. This item to be given first priority.

8. Grant permits for 50% additional boat slips and support facilities provided that no additional inlets be cut from the Gulf or Bay.

9. Investigate alternative sites for providing marina facilities on Sanibel.

Section 2.5.7: Conservation†

Section 2.5.8: Community Design†

ARTICLE 3: DEVELOPMENT REGULATIONS

Part 3.1: Definitions†

Part 3.2: Maps†

Part 3.3: General Requirements†

Part 3.4: Permitted Uses†

Part 3.5: Subdivisions†

Part 3.6: Mobile Homes and Recreation Vehicles†

Part 3.7: Flood and Storm Proofing

Section 3.7.1: Flood Proofing

A development permit shall be granted only if the applicant has demonstrated that the proposed development:

1) provides for the elevation of the lowest floor to be used for habitation or commercial purposes of all new construction or substantial improvements of existing buildings;

    a) to or above 13.5 feet mean sea level in all areas within five hundred (500) feet of San Carlos Bay, Pine Island Sound, Blind Pass and the Gulf of Mexico.

    b) in all other areas of the Island to or above 7.5 feet mean sea level until the Administrator of the National Flood Insurance program has provided surface elevations for the 100 year flood then to or above the elevation specified as the level of the 100 year flood .

2) provides that any portion of any new construction or substantially improved building required to be elevated to or above 13.5 feet mean sea level that portion of the structure which is below 13.5 feet mean sea level will only be used for parking, storage, utility rooms, workshops and other uses normally associated with accessory buildings;

3) provides that any portion of any new construction or substantially improved building required to be elevated to or above 13.5 feet mean sea level which is below 13.5 feet mean sea level with the exception of support pilings shall be constructed of "breakaway" or other material which will allow storm-driven wind and water to pass through the lower portions of such buildings without threatening the integrity of the elevated portions of the building;

4) provides that in any new construction or substantially improved building required to be elevated to 13.5 feet mean sea level, all utility service systems shall be flood proofed to at least the first habitable floor;

5) provides that all utility facilities be flood proofed to at least 13.5 mean sea level.

Section 3.7.2: Certification of Flood Proofing†

Section 3.7.3: Emergency Shelter Space†

Section 3.7.4: Emergency Water†

Section 3.7.5: Non-resident Structures†

Part 3.8: Site Preparation

Section 3.8.1: Site Preparation

In addition to all other standards of the Comprehensive Plan any development which is carried out within the City of Sanibel shall be subject to the following standards during development:

1) During development and construction, adequate protective measures shall be provided to minimize damage from surface water to the cut face of excavations or the sloping surfaces of fills.

2) Erosion and sediment control measures shall be coordinated with the sequence of grading, development, and construction operations. Control measures such as hydroseeding, berms, interceptor ditches, terraces, and sediment traps, shall be put into effect prior to the commencement of each increment of the development/construction process.

3) Sediment basins (debris basins, desilting basins, or silt traps) shall be installed in conjunction with the initial grading

operations and maintained through the development process to remove sediment from runoff waters draining from land undergoing development.

4) Soil and other materials shall not be temporarily nor permanently stored in locations which would result in the unnecessary destruction of vegetation.

5) The permanent vegetation shall be installed on the construction site as soon as utilities are in place and final grades are completed.

6) Final grading and removal of vegetation shall not occur more than 30 days prior to scheduled finishing.

7) All on-site facilities shall be properly maintained by the owner so that they do not become nuisances. Nuisance conditions shall include but not be limited to: improper storage resulting in uncontrolled runoff and overflow; stagnant water with concomitant algae growth, insect breeding and odors; discarded debris; unnecessary noise; and safety hazards created by the facility's operations.

8) Construction waste materials or construction by-products shall be controlled on site to prevent nuisance and shall be disposed of in the same manner as other solid waste.

Part 3.9: Environmental Performance Standards

Section 3.9.1: Development in the Gulf Beach, Gulf Beach Ridge and Special Blind Pass Zones

A development permit shall be granted for development or site alteration only if the applicant can demonstrate that the proposed development or site alteration:

Geology

1) will not result in diminution in the amount of sand, silt, shell, sediment, or other geologic component which make up the beach, or interfere with natural patterns of wind and water movement of sand, silt, shell, sediment or other geologic components of the beach;

2) will not result in the removal of sand, silt, shell, sediment or other geological component of the Gulf Beach Ridge, reduce the elevation of any portion of the ridge, or otherwise alter the natural configuration of the ridge in a manner that diminishes the effectiveness of the ridge as a protective barrier against storm surge;

Hydrology

3) provides for the gradual and dispersed drainage of surface runoff such that runoff within the boundaries of the parcel proposed for development will approximate natural rates, volumes and direction of flow; included shall be a requirement for containment on site of the runoff from a 5 year storm (unless otherwise provided in common with other site); and further, coverage with impermeable surfaces shall be no greater than 20% of the gross area of the parcel proposed for development;

4) will not disturb, break or penetrate the aquiclude or clay layer at the bottom of the freshwater lens, permit saltwater intrusion or otherwise endanger the integrity of the freshwater lens. If in order to comply with the flood

proofing regulations of this Plan it is necessary to drive pilings below the level of the aquiclude, such penetration shall be sealed according to the best technology available to avoid saltwater intrusion;

5) will not involve the use of a septic tank unless the design and location of the proposed disposal system is in strict compliance with Section 10D-6 of the State Sanitary Code, as interpreted by the City Manager; further, any existing or proposed residential or other use which generates sewage or other waste water shall be connected to a sewer whenever such service becomes available as determined by the City;

6) will not result in the discharge of treated or untreated sewage or other human waste from a boat into the waters of the City of Sanibel.

Vegetation

7) will not result, in areas seaward of the Coastal Construction Setback Line, in the direct or indirect removal, destruction, depletion or digging out of vegetation which contributes to beach stability, including but not limited to Sea Oats, Uniola paniculata; Fingergrass, Chloris glauca; Railroad vine, Ipomea pescaprae; Sea purslane, Sesuvium portulacastrum; and Seagrape, Coccoloba uvifera;

8) will not involve, in areas landward of the Coastal Construction Setback Line, the unnecessary removal of native vegetation which stabilizes soils, serves as a buffer to storm surge, and provides wildlife habitats as identified in 3.1.9 (11); in no case shall greater than 30% of the gross area of any parcel proposed for development be cleared unless the additional area is covered with the Australian pine, Casuarina; the Brazilian pepper, Schinus terebinthifolius; or Melaleuca, Melaleuca quinquenervia. Any portion of the parcel in excess of 30% which is so cleared shall be revegetated with native or non-competing exotic species of plant which stabilize soil and serve as a storm buffer;

9) provides for the removal of exotic species of plant which outcompete or otherwise displace native species including the Brazilian pepper or Florida holly, Schinus terebinthifolius; the Cajeput or Punk tree, Melaleuca quinquenervia, within the boundaries of the parcel proposed for development or site alteration;

10) provides that all landscaping will only involve the use of native species of plants or exotic species which do not outcompete or otherwise displace native species of plant.

Wildlife

11) will minimize any necessary interference with the natural use of the beach for feeding, foraging, resting, nesting and breeding by indigenous and migratory birds, shellfish, marine fishes, sea turtles and other wildlife. Such interference shall include the destruction or diminution of organisms or material upon which wildlife feed.

Miscellaneous

12) will not interfere with the customary rights of the public to access to and use of the active beach.

Section 3.9.2: Development in the Interior Wetland Zone

A development permit shall be granted for development or site alteration in the Interior Wetland Zone only if the applicant has demonstrated that the proposed development or site alteration:

Geology-Hydrology

1) provides that all construction, excavation or improvement of any natural or artificial body of water will result in:

   a) a depth of greater than 4 feet during the lowest water stage of the year in order to restrict the growth of rooted aquatics such as cattails;

   b) a bottom slope and alignment that will produce maximum water movement by prevailing winds;

2) provides for the gradual and dispersed drainage of surface runoff such that runoff within the boundaries of the parcel proposed for development will approximate natural rates, volumes and direction of flow; included shall be a requirement for containment on site of the runoff from a 5 year storm (unless otherwise provided in common with other site); and further, coverage with impermeable surfaces shall

be no greater than 10% of the gross area of the parcel proposed for development in the Wetland Lowlands and 20% of the gross area of the parcel proposed for development in the Wetland Uplands;

3) will not impede, impound or otherwise interfere with the natural flow of water in the Sanibel River or Slough;

4) will not disturb, break or penetrate the aquiclude or clay layer at the bottom of the freshwater lens, permit saltwater intrusion or otherwise endanger the integrity of the freshwater lens. If in order to comply with the flood proofing regulations of this Plan it is necessary to drive pilings below the level of the aquiclude, such penetration shall be sealed according to the best technology available to avoid saltwater intrusion;

5) will not involve the use of a septic tank unless the design and location of the proposed disposal system is in strict compliance with Section 10D-6 of the State Sanitary Code, as interpreted by the City Manager; further, any existing or proposed residential or other use which generates sewage or other waste water shall be connected to a sewer whenever such service becomes available as determined by the City;

6) will not result in the discharge of treated or untreated sewage or other human waste from a boat into the waters of the City of Sanibel.

Vegetation

7) will not involve the unnecessary removal of native vegetation which stabilizes soils, increases recharge and provides wildlife habitats; in no case shall greater than 20% in Wetland Lowlands and 30% in the Wetland Uplands of the gross area of any parcel proposed for development be cleared unless the additional area is covered with the Australian pine, Casuarina; the Brazilian pepper, Schinus terebinthifolius; and the Melaleuca, Melaleuca quinquenervia. Any portion of the parcel in excess of 20% in the Wetland Lowlands and 30% in Wetland Uplands which is so cleared shall be revegetated with native non-competing exotic species of plant which stabilize soil, increase recharge and provide wildlife habitats;

8) provides for the removal of exotic species of plants which outcompete or otherwise displace native species including the Brazilian pepper or Florida holly, Schinus terebinthifolius; and the Cajeput or Punk tree, Melaleuca quinquenervia, within the boundaries of the parcel proposed for development or site alteration.

9) provides that all landscaping will only involve the use of native species of plant or non-competing species of plant ;

Wildlife

10) will minimize any necessary interference with the natural use of the interior wetlands for feeding, foraging, resting, nesting and breeding by indigenous and migratory birds, shellfish, fishes and other wildlife. Such interference shall include the destruction or diminution of organisms or material upon which wildlife feed;

Wildfire

11) includes safeguards against wildfire, and if possible is designed in a manner to permit use of controlled fire in the interior wetland as a means of managing non-woody vegetation and of destroying accumulated natural debris which represents a wildfire hazard.

Section 3.9.3: Development in the Mid-Island Ridge Zone

A development permit shall be granted for development or site alteration in the Mid-Island Ridge Zone only if the applicant has demonstrated that the proposed development or site alteration:

Geology

1) will not result in the permanent unnecessary lowering of the natural elevation of any portion of the parcel proposed for development by excavation, digging, grading, or other removal of sand, silt, shell, or soil, except for the installation of swimming pools.

Hydrology

2) provides for the gradual and dispersed drainage of surface runoff such that runoff within the boundaries of the parcel proposed for development will approximate natural rates, volumes and direction of flow; included shall be a requirement for containment on site of the runoff from a 5 year storm (unless otherwise provided in common with other site); and further, coverage with impermeable surfaces shall be no greater than 30% of the gross area of the parcel proposed for development;

3) will not disturb, break or penetrate the aquiclude or clay layer at the bottom of the freshwater lens, permit saltwater intrusion or otherwise endanger the integrity of the freshwater lens. If in order to comply with the floodproofing regulations of this Plan it is necessary to drive pilings below the level of the aquiclude, such penetration shall be sealed according to the best technology available to avoid saltwater intrusion;

4) will not involve the use of a septic tank unless the design and location of the proposed disposal system is in strict compliance with Section 10D-6 of the State Sanitary Code, as interpreted by the City Manager; further any existing or proposed residential or other use which generates sewage or other waste water shall be connected to a sewer whenever such service becomes available as determined by the City;

5) will not result in the discharge of treated or untreated sewage or other human waste from a boat into the waters of the City of Sanibel.

Vegetation

6) will not involve the unnecessary removal of native vegetation which stabilizes soil and provides wildlife habitats; in no case shall greater than 30% of the gross area of any parcel proposed for development be cleared unless the additional area is covered with the Australian pine, Casuarina; the Brazilian pepper, Schinus terebinthifolius; and the Melaleuca, melaleuca quinquenervia. Any portion of the parcel in excess of 30% which is so cleared shall be revegetated with native or non-competing species of plant;

7) provides for the removal of exotic species of plant which outcompete or otherwise displace native species including the Brazilian pepper, or Florida holly, Schinus terebinthifolius, the Cajeput or Punk tree, Melaleuca quinquenervia within the boundaries of parcel proposed for development or site alteration.

Section 3.9.4: Development in the Mangrove Forest Zone

A development permit shall be granted for development or site alteration in the Mangrove Forest Zone only if the applicant has demonstrated that the proposed development or site alteration:

Geology

1) will not result in the permanent lowering of the natural elevation of any portion of the parcel proposed for development by excavation, ditching, dredging, digging, filling or other disturbance of sand, silt, soil, sediment, accumulated detritus, or other geologic or biologic component of the mangrove forest except for that activity necessary to:

   a) maintain freshwater levels in the interior wetland;
   b) protect the health, safety and welfare of the City from disease-carrying insects;
   c) manage the mangrove forest as a viable natural community.

Hydrology

2) will not restrict, impede, impound or otherwise interfere with the tidal flow or influence in the mangrove forest, or similarly interfere with drainage in the mangrove forest;

3) provides for the gradual and dispersed drainage of surface runoff such that runoff from within the boundaries of the parcel proposed for development will approximate natural rates, volumes and direction of flow; included shall be a requirement for containment on site of the runoff from a 5 year intensity

storm and further, coverage with impermeable surfaces shall be minimized and in any event shall not exceed 1% of the gross area of the parcel proposed for development;

4) will not disturb, break or penetrate the aquiclude or clay layer at the bottom of the freshwater lens, permit saltwater intrusion or otherwise endanger the integrity of the freshwater lens. If in order to comply with the floodproofing regulations of this Plan it is necessary to drive pilings below the level of the aquiclude, such penetration shall be sealed according to the best technology available to avoid saltwater intrusion;

5) will not involve the use of a septic tank or other mechanisms or devices that could result in the discharge of sewage or other waste within the Mangrove Forest;

6) will not result in the discharge of treated or untreated sewage or other human waste from a boat into the waters of the City of Sanibel.

Vegetation

7) will not involve the unnecessary removal of any native vegetation which exists as a natural buffer to storm surge, stabilizes soils or provides wildlife habitats, including but not limited to Red mangrove, <u>Rhizophora mangle</u>; Black mangrove, <u>Avicennia germinans</u>; and White mangrove, <u>Laguncularia racemosa</u>;

8) provides for the removal of exotic species of plant which outcompete or otherwise displace native species including the Brazilian pepper or Florida holly, <u>Schinus terebinthifolius</u>; the Cajeput or Punk tree, <u>Melaleuca quinquenervia</u> within the boundaries of the parcel proposed for development or site alteration;

9) provides that all landscaping will only involve the use of native species of plant or non-competing species of plant.

Wildlife

10) will minimize any interference with the use of the mangrove forest for feeding, foraging, resting, nesting, shelter and breeding by indigenous and migratory birds, shellfish, fish and other indigenous wildlife. Such interference shall include the destruction or diminution of organisms or material upon which wildlife feed.

Section 3.9.5: Development in or Affecting the Bay Beach Zone

A development permit shall be granted for development or site alteration in the Bay Beach Zone only if the applicant has demonstrated that the proposed development or site alteration:

Geology

1) will not result in the diminution in the amount of sand, silt, shell, sediment or other geologic component which make up the beach, or interfere with natural patterns of wind and water movement of sand, silt, shell, sediment or other geologic component of the beach.

Hydrology

2) provides for the gradual and dispersed drainage of surface runoff such that runoff within the boundaries of the parcel proposed for development will approximate natural rates, volumes and direction of flow; included shall be a requirement for containment on site of the runoff from a 5 year storm, (unless otherwise provided in common with other site); and further, coverage with impermeable surfaces shall be no greater than 10% of the gross area of the parcel proposed for development;

3) will not involve the use of a septic tank or other mechanisms or devices that could result in the discharge of sewage or other waste within the Bay Beach;

4) will not result in the discharge of treated or untreated sewage or other human waste from a boat into the waters of the City of Sanibel.

Vegetation

5) will not result in the direct or indirect removal, destruction, depletion, or digging out of natural vegetation which contributes to beach stability, including

but not limited to Sea oats, Uniola paniculata; Fingergrass, Chloris glauca; Railroad vine, Ipomea pescaprae; Sea purslane, Sesuvium portulacastrum; Red mangrove, Rhizophora mangle; Black mangrove, Avicennia germinans; White mangrove, Languncularia racemosa; and Seagrape, Coccoloba uvifera;

6) provides for the removal of exotic species of plant which outcompete or otherwise displace native species including the Brazilian pepper or Florida holly, Schinus terebinthifolius; the Cajeput or Punk Tree, Melaleuca quinquenervia within the boundaries of parcel proposed for development or site alteration;

7) provides that all landscaping will only involve the use of native species of plant or non-competing species of plant.

Wildlife

8) will minimize any necessary interference with the use of the beach for feeding, foraging, resting, nesting and breeding by indigenous and migratory birds, sea turtle, shellfish, marine fishes and other wildlife. Such interference shall include the destruction or diminution of organisms or material upon which wildlife feed.

Miscellaneous

9) will not interfere with the customary rights of the public to access to and use of the beach.

Section 3.9.6: Development in the Filled Land Zone

A development permit shall be granted for development or site alteration in the Filled Land Zone only if the applicant has demonstrated that the proposed development or site alteration:

Geology-Hydrology

1) provides that all construction, excavation or improvement of any natural or artificial body of water will result in:

a) a depth of greater than 4 feet during the lowest water stage of the year in order to restrict the growth of rooted aquatics such as cattails;

b) a bottom slope and alignment that will produce maximum water circulation by prevailing winds;

2) provides for the gradual and dispersed drainage of surface runoff such that runoff from within the boundaries of the proposed development will approximate natural rates, volumes and direction of flow; included shall be a requirement for containment on site of the runoff from a 5 year storm (unless otherwise provided in common with other site); and further, coverage with impermeable surfaces shall be no greater than 30% of the gross area of the parcel proposed for development;

3) will not disturb, break or penetrate the aquiclude or clay layer at the bottom of the freshwater lens, permit saltwater intrusion or otherwise endanger the integrity of the freshwater lens. If in order to comply with the floodproofing regulations of this Plan it is necessary to drive pilings below the level of the aquiclude, such penetration shall be sealed according to the best technology available to avoid saltwater intrusion;

4) will not involve the use of a septic tank unless the design and location of the proposed disposal system is in strict compliance with Section 10D-6 of the State Sanitary Code, as interpreted by the City Manager; further any existing or proposed residential or other use which generates sewage or other waste water shall be connected to a sewer whenever such service becomes available as determined by the City;

5) will not result in the discharge of treated or untreated sewage or other human waste from a boat into the waters of the City of Sanibel.

Vegetation

6) will not involve the unnecessary removal of native vegetation which stabilizes soils, increases recharge and provides wildlife habitats; in no case shall greater than 30% of the gross area of any parcel proposed for development be cleared unless the additional area is covered with the Australian pine, Casuarina; the Brazilian pepper, Schinus terebinthifolius; and the Melaleuca, Melaleuca quinquenervia. Any portion of this parcel in excess of 30% which has been cleared shall be revegetated with native or non-competing exotic species of plant which stabilize soil,

increase recharge and provide wildlife habitats;

7) provides for the removal of exotic species of plant which outcompete or otherwise displace native species including the Brazilian pepper or Florida holly, Schinus terebinthifolius; the Cajeput or Punk tree, Melaleuca quinquenervia within the boundaries of the parcel proposed for development or site alteration;

8) provides that all landscaping will only involve the use of native species of plants or exotic species which do not out-compete nor otherwise displace native species of plant

Section 3.9.7: Coverage and Clearance in Commercial Districts

In those areas designated as Commercial C on the permitted uses map:

1) Notwithstanding the provisions of any other section of this part, a developer of a commercial use in an area designated as Commercial District C on the Commercial Districts Map may:

   a) cover up to 50% of the gross area of the parcel proposed for development with impermeable surfaces; and

   b) clear vegetation from up to 50% of the gross area of the parcel proposed for development.

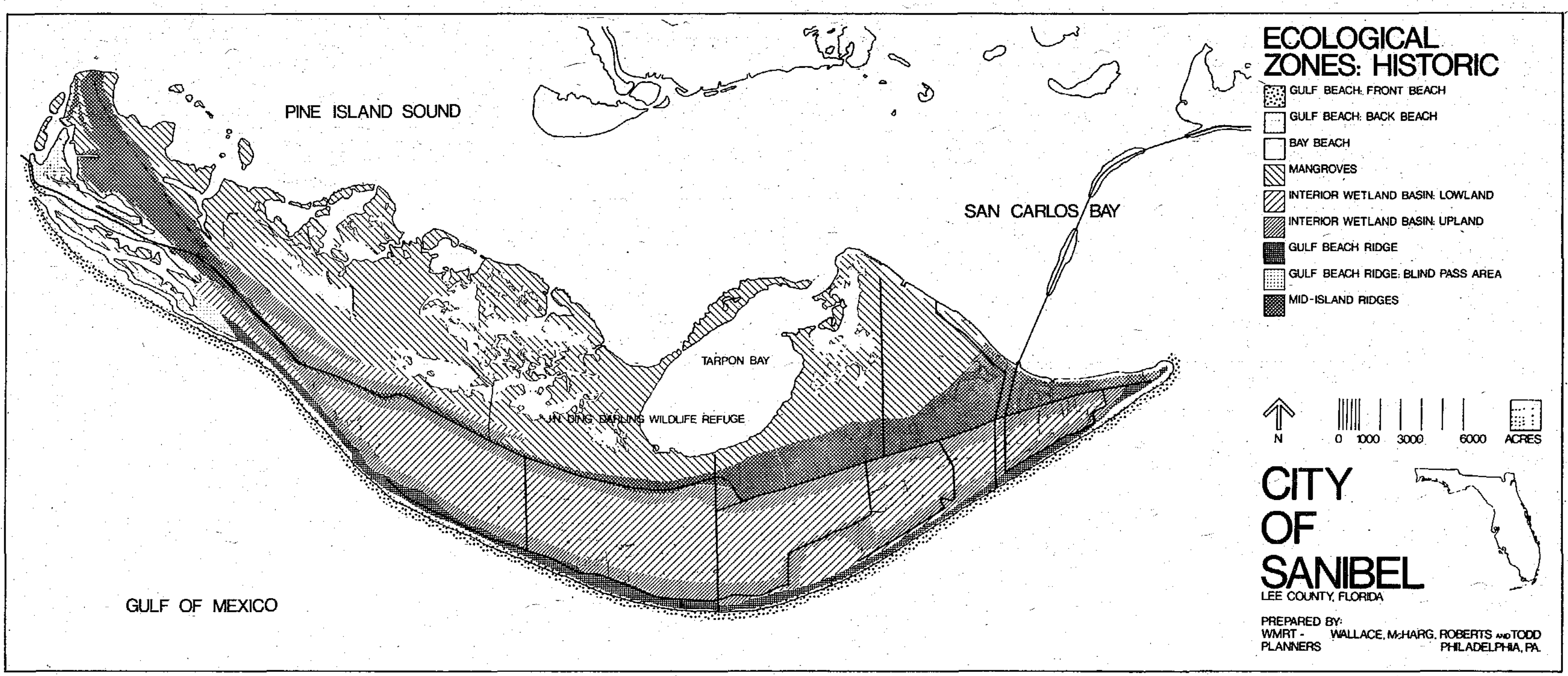
2) Any developer of a commercial use desiring to clear in excess of that permitted or required in the ecological zone in which the proposed development is located as provided by this section shall prepare a site plan indicating the vegetation to be removed. Any rare vegetation or other particularly valuable stands or examples of vegetation shall be preserved in the 50% of the parcel that is not cleared.

Part 3.10: Paved Surface Construction Standards

Section 3.10.1: Paving Materials

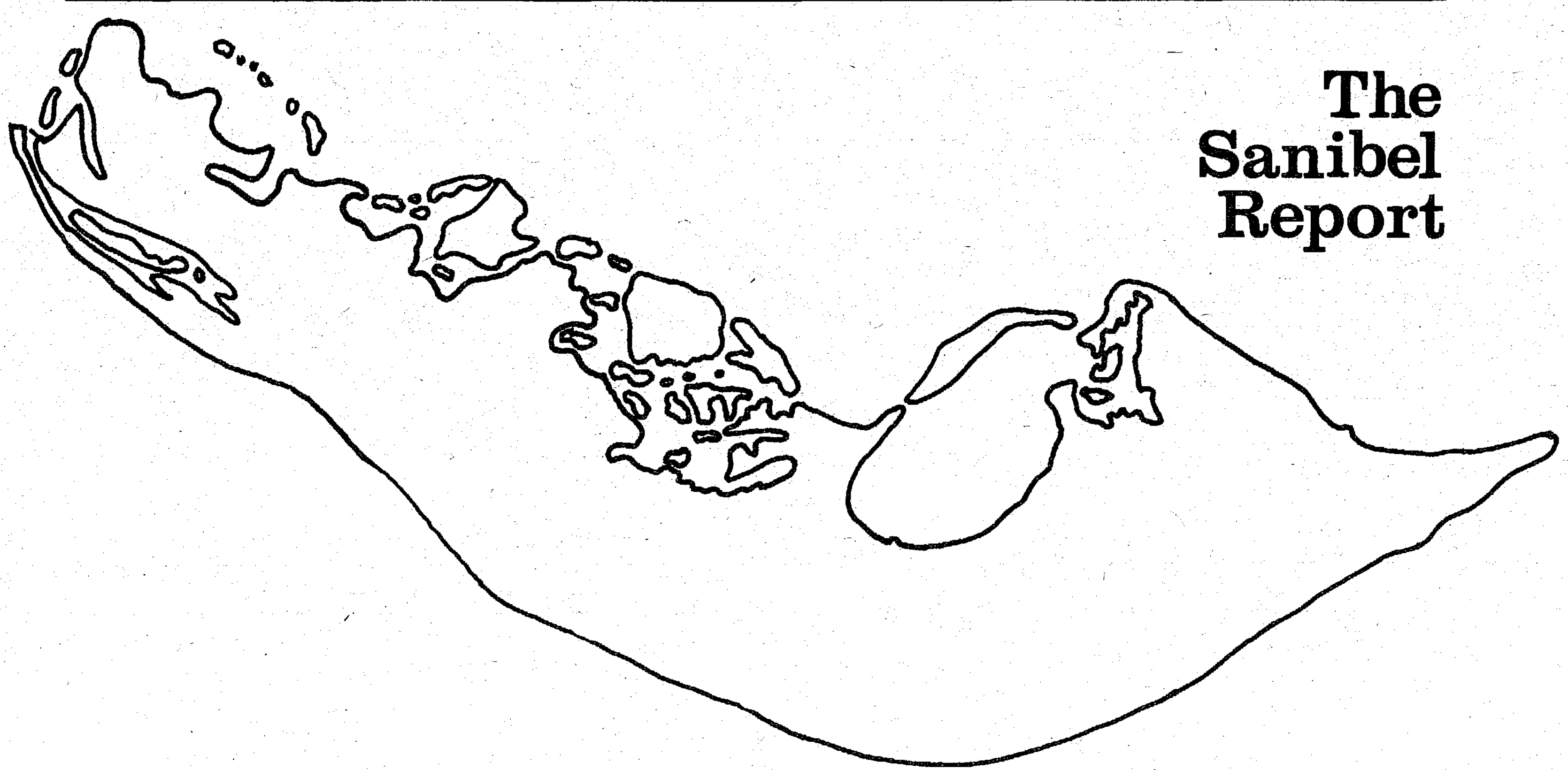
In order to reduce surface runoff, attendant erosion and degradation of water quality, all paved surfaces shall be constructed of permeable material as is best practicable taking into account the intensity of use anticipated and best engineering and construction practices. When paved surfaces are required they shall be constructed of asphalt, or other material of equal durability, and shall be constructed in accordance with City standards.

ARTICLE 4: ADMINISTRATIVE REGULATIONS †



ECOLOGICAL ZONES: HISTORIC
GULF BEACH: FRONT BEACH
GULF BEACH: BACK BEACH
BAY BEACH
MANGROVES
INTERIOR WETLAND BASIN: LOWLAND
INTERIOR WETLAND BASIN: UPLAND
GULF BEACH RIDGE
GULF BEACH RIDGE: BLIND PASS AREA
MID-ISLAND RIDGES
PINE ISLAND SOUND
SAN CARLOS BAY
TARPON BAY
J.N. DING DARLING WILDLIFE REFUGE
GULF OF MEXICO
N
0 1000 3000 6000 ACRES
CITY OF SANIBEL
LEE COUNTY, FLORIDA
PREPARED BY:
WMRT - WALLACE, McHARG, ROBERTS AND TODD
PLANNERS PHILADELPHIA, PA.

Appendixes



The Sanibel Report

APPENDIX 1

APPENDIX 1

HYDROLOGY

by Thomas M. Missimer

For many years, Sanibel Island, Florida, has been an attraction to both tourists and shell collectors alike. In the past decade tourism and urban development have rapidly grown on the island (WMRT, 1975). During this time period, the natural hydrologic system on the island has been modified so as to provide a more comfortable environment for residents and visitors. These modifications include: the excavation of drainage ditches for mosquito control purposes, the excavation of canals to provide boat access to tidal water bodies, the excavation of real estate lakes to provide fill material to raise the land surface altitude, the construction of paved roadways for transportation, the construction of shallow wells for irrigation, the construction of deep artesian wells to provide water for municipal supply, and implacement of septic tanks.

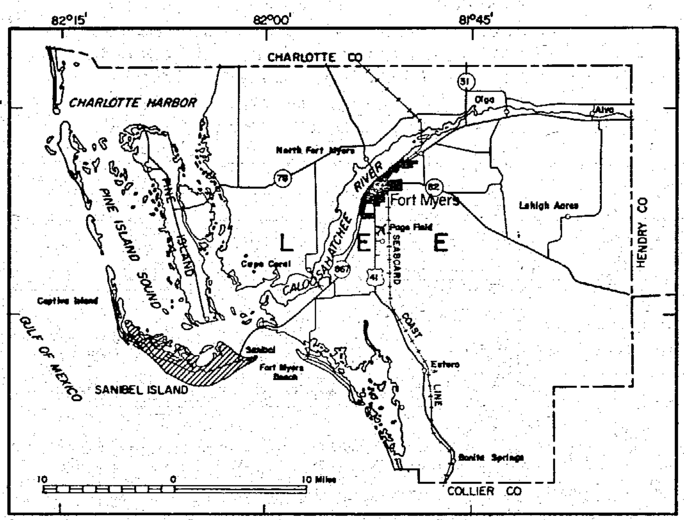
Most of the modifications to the hydrologic system on Sanibel Island have been effective in their purposes, but these modifications have also had numerous detrimental effects on the natural environment. If the unique natural environment on the island is to be preserved for the enjoyment of the present and future generations, proposed modifications to the hydrologic system must be carefully evaluated before being permitted.

The acceleration of urban development in the 1970's has necessitated the need for detailed information with regard to the natural and man-altered hydrologic system on Sanibel Island. It is the purpose of this report to provide a concise summary and interpretation of the available hydrologic data from Sanibel Island with emphasis on criteria for proper management of the water resources. A detailed scientific analysis of all data is beyond the scope of this report.

AREA DESCRIPTION

Sanibel is a barrier island located along the southwest Florida coast (Figure 1). It is the southernmost island in a chain that extends about 50 miles to the north. The island has a curved shoreline with the convex portion facing south and generally has an east-west axis. It comprises a land area of 10,730 acres (Veri and Warner, 1975) or about 18 square miles (Missimer, 1973a).

The island consists dominantly of numerous sets of individual beach ridges with intermediate swales as described by Missimer (1973a; 1973b). Land surface on most of Sanibel lies three to five feet above mean sea level with the highest point being nearly 11 feet above mean sea level near Wulfert (Figure 2). High beach ridges at Wulfert and others extending along the Sanibel-Captiva Road to the east form a topographic high, which is a surface water drainage divide. A similar set of high beach ridges causes a drainage divide to occur in the south running parallel to Gulf Drive on the west of Tarpon Bay Road and nearly parallel to the shoreline on the east side. The area between these surface water divides consists of low-lying beach ridges and swales



Base map from U.S.G.S. Topographic map
(from Boggess, 1974a)

Fig. 1 - Map showing the location of Sanibel Island.

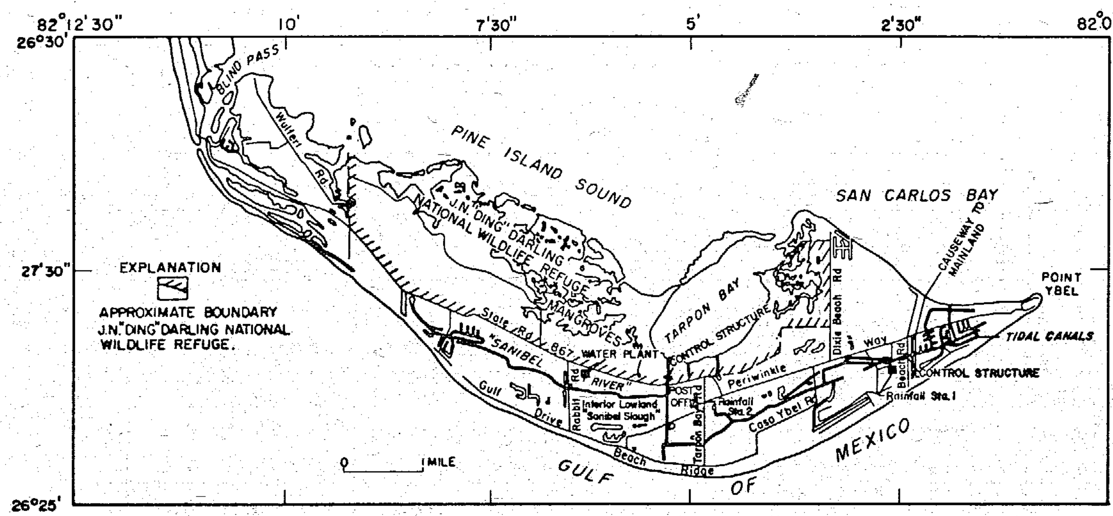


Fig. 2 - Map showing the road network, interior drainage system, rainfall gauge locations, and general geographic localities on Sanibel Island.

and is known as the "interior wetlands." The Sanibel Slough or "River" runs through this area.

Lush vegetation covers most of the natural parts of Sanibel. Mangrove swamp is dominant along the low-lying northern shore, in the vicinity of Blind Pass, and in isolated parts of the interior wetlands (See Heald and Tabb, 1976). The higher beach ridge areas contain various shrubs, trees, and grasses while the wetland areas contain marsh species (See Alexander, (1975).

In the natural state, the only non-tidal surface water bodies on Sanibel were some isolated ponds located in the deeper swales and the Sanibel Slough. Today the island contains numerous man-made lakes, ponds, canals and ditches.

Climatic Conditions

The City of Sanibel has a subtropical climate with an estimated average temperature of about 74°F (Boggess, 1974a). An average temperature of about 83°F occurs over the month of August and an average of 64°F occurs over January. A "killing" frost occurs once every few years (Provost, 1953).

A prevailing mild easterly wind blows across Sanibel most of the year except during the passing of winter frontal systems and tropical storms. A more complete discussion of climate is given in Riggs (1976).

RAINFALL

Daily rainfall is monitored by the U.S. Geological Survey at two locations on Sanibel Island. Station 1 is located at the home of Mr. Robert England on the eastern part of the island and Station 2 is located near the Post Office along Tarpon Bay Road (See Figure 2). Both gauges are the standard 8-inch type, but Station 2 is also equipped with an automatic recorder, which makes it the more accurate of the two.

In Lee County, about 70 percent of the total annual rainfall occurs during the wet season, June through October. Only about 30 percent of the annual total occurs during the dry season, November through May (Missimer and Boggess, 1974). This same rainfall pattern occurs on Sanibel Island as is shown in Table 1, where monthly and annual rainfall totals are shown for Stations 1 and 2 on Sanibel and for Page Field near Fort Myers.

Most of the rainfall on Sanibel Island, like the mainland, occurs during sporadic thunderstorms, which occur randomly throughout the wet season. During the early part of

	1971			1972			1973			1974			1975		
	S#1	S#2	P.F.	S#1	S#2	P.F.	S#1	S#2	P.F.	S#1	S#2	P.F.	S#1	S#2	P.F.
Jan.	2.45	-	0.85	1.32	1.19	0.77	3.60	3.16	3.14	0.03	0.08	0.36	0.37	1.38	0.26
Feb.	1.90	-	1.55	2.07	1.77	2.14	2.37	1.19	2.23	0.51	0.42	0.81	0.62	0.38	0.27
Mar.	0.14	-	0.55	5.35	4.75	4.72	4.02	3.12	3.89	0.00	0.00	0.03	0.90	0.67	1.47
Apr.	0.90	-	0.70	0.00	0.00	0.27	1.43	1.57	1.71	0.56	0.27	0.11	1.25	0.97	0.80
May	1.33	-	3.97	0.52	0.57	5.20	2.15	0.23	0.78	3.44	1.95	2.40	3.97	2.79	2.78
Jun.	2.67	-	6.18	7.82	7.34	7.86	6.13	5.39	3.99	18.94	16.26	20.10	2.11	2.29	12.35
Jul.	3.59	-	9.50	3.84	3.57	9.72	5.87	7.52	9.57	7.73	9.68	14.47	-	-	10.00
Aug.	9.50	6.36	8.06	8.49	3.57	16.22	7.68	6.23	8.66	7.05	5.32	7.70	-	-	-
Sept.	15.25	17.88	9.21	4.17	3.61	2.33	9.47	8.94	8.38	4.95	3.16	4.31	-	-	-
Oct.	5.16	5.40	6.49	1.03	0.94	2.20	0.86	0.36	0.16	0.65	0.19	0.19	-	-	-
Nov.	0.33	0.42	0.16	5.41	5.26	3.85	0.66	0.62	0.10	0.72	1.36	1.46	-	-	-
Dec.	1.14	1.06	0.30	1.32	1.30	1.43	1.95	1.73	1.72	1.67	0.68	0.89	-	-	-
Tot.	44.36	-	47.32	42.34	37.75	56.71	46.19	40.06	44.33	46.15	39.37	52.83	-	-	-

S#1 is Station 1 on Sanibel Island
S#2 is Station 2 on Sanibel Island
P.F. is Page Field, near Fort Myers

Table 1 - Monthly and Annual Rainfall at Sanibel Stations 1 and 2 and at Page Field (in inches)

the wet season, most of these storms form to the southeast and move to the west and northwest. Often the storms do not reach Sanibel during this time period. This rainfall pattern is responsible for larger annual totals occurring on the east coast of Florida and progressively lower annual totals occurring to the west (Benson and Gardner, 1974). During the later part of the wet season, thunderstorms form at any place or any time and a more random distribution occurs.

The Sanibel Island rainfall data fits the regional pattern. For example, during the three-year period from 1972 through 1974, the Page Field Station averaged 51.29 inches while Stations 1 and 2 on Sanibel averaged 44.89 and 39.06 inches, respectively. The distribution of rainfall varies considerably from point to point on the island over any given year. Hence, for calculations used later in this report, an average value of 42.00 inches is used for the entire island (average of Stations 1 and 2).

HURRICANES AND TROPICAL STORMS

Hurricanes and less intense tropical storms are significant climatic factors which sometimes affect the hydrologic system of Sanibel Island. In the past, intense rainfall during hurricanes and tropical storms has caused extensive flooding, and complete tidal overtopping of the island has occurred during several severe hurricanes.

Many intense hurricanes have passed over or near Sanibel Island. Historically, Hurricane Donna in 1960 and the "Labor Day" Hurricane in 1935 caused extensive flooding, but complete overtopping did not occur. The last documented storm which completely flooded the island with seawater occurred in 1926 and was responsible for the failure of agriculture on the island (Veri and Warner, 1975). Other intense hurricanes which caused significant tidal flooding occurred in 1921, 1910, 1894, and 1873.

During the time period 1830 to 1968, 23 hurricanes and 23 tropical storms or depressions passed within 50 miles of Lee County (U.S. Army Corps of Engineers, 1969). According to Jordan (1973), the probability of a tropical storm or hurricane passing through the Gulf of Mexico is 50 percent for a given season. A more complete discussion of hurricane frequency in relation to Sanibel Island is given by Riggs (1976).

Geologic Setting

DEEP GEOLOGY

Sanibel Island is a thin veneer of quartz sand and shell lying on top of a thick accumulation of limestone, sandy carbonate muds, dolomites, and quartz sands. The entire sequence is more than 15,000 feet thick. Only the upper 1,000 feet of these sediments are of any great significance in the understanding of the island's hydrology and, thus, these are the only strata discussed herein (Figure 3).

The deepest geologic unit penetrated on the island is the Suwannee Limestone of Oligocene age. This unit is encountered at depths varying between 650 and 750 feet below land surface. It consists mostly of limestone with some interbedded quartz sand and carbonate mud.

The lower Miocene Tampa Limestone lies unconformably above the Suwannee Limestone. This formation is poorly defined and quite impossible to distinguish from the overlying unit. It

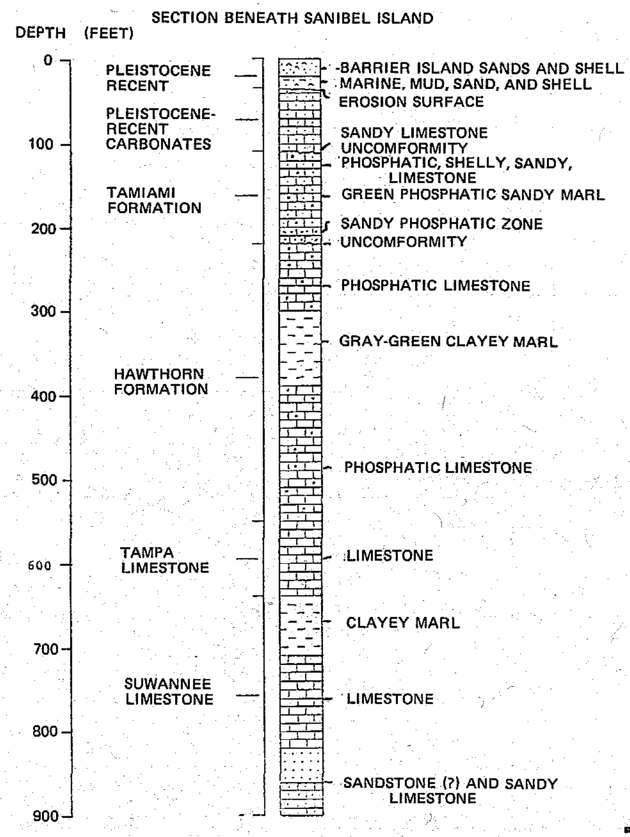


Fig. 3 - Generalized geology of the deep formations underlying Sanibel Island. (from Missimer, 1973a)

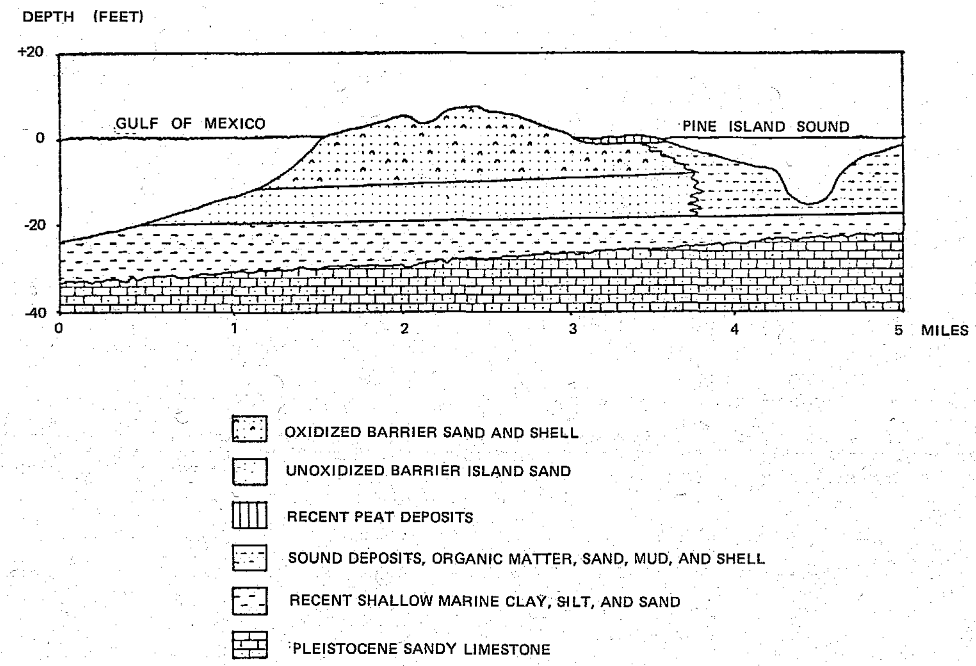


Fig. 4 - Generalized geologic section of Sanibel Island perpendicular to the island axis. (from Missimer, 1973a).

consists primarily of phosphatic sandy limestone with beds of marly limestone and carbonate mud.

The middle Miocene Hawthorn Formation lies conformably on top of the Tampa Limestone. This formation of extremely heterogeneous, consisting of light gray phosphatic limestone, sandy carbonate mud and gray-green carbonate clay. The top of the unit occurs at depths ranging from about 160 feet to about 250 feet below land surface. Folding in the subsurface has been suggested as the cause for extreme depth variation to the top of each of the above discussed formations. This hypothesis was made on the basis of seismic reflection data (Missimer, 1974; Missimer and Gardner, 1975).

The Tamiami Formation overlies the Hawthorn Formation unconformably. This unit ranges from middle Pliocene to late Miocene in age (D. Peck, Dept. of Geology, Florida State University, personal communication) and consists of a complex sequence of green carbonate clays, phosphatic sands, and sandy limestone. It is usually encountered at depths varying between 50 and 80 feet below land surfaces.

A Plio-Pleistocene age limestone unit lies above the Tamiami. This unit probably correlates to the Caloosahatchee Marl-Fort Thompson Formation sequence on the mainland. The dominant lithology of this unit is light gray, hard limestone, which contains numerous solution cavities.

There is a distinct lack of detailed information on the deep geologic formations underlying Sanibel Island. All of the available data used in this discussion were taken from Missimer (1973a) and Boggess (1974a).

SHALLOW GEOLOGY

The Sanibel Island sequence was deposited on top of the previously described Pleistocene limestone unit. Three distinct stratigraphic units are represented in the shallow sequence (Figure 4). The lowermost, lying immediately above the limestone, consists of gray carbonate mud and clay mixed with variable amounts of quartz sand, shell, and limestone fragments. This unit is generally fine-grained material and usually confines the underlying limestone, but localities do exist where this unit consists dominantly of sand and shell. A fine to very fine gray sand overlies the mud stratum. This sand is nearly homogeneous and generally contains about one to three percent carbonate mud. The uppermost unit consists of beach ridge sand and shell. These strata are heterogeneous with the shell lenses and sand beds, oriented generally parallel to the direction of associated beach ridges (See below).

A number of minor sediment deposits occur on or around the island. Some fine-grained organic muds occur in areas bordering Pine Island Sound. Several feet of peat have been deposited adjacent or beneath the older mangrove forests. Minor soil development has occurred on the island where fine material has filled some of the low-lying swales between beach ridges. Some "freshwater" organic marls have been reported to be forming in parts of the interior wetlands area (Tabb et al, 1976).

It is important to note the coarsest deposits in the island sequence occur near the surface and the mean grain diameter of the sediments decreases with depth (Figure 5). Hence, permeability of the sediment decreases with depth.

The sand and shell portions of the island consist of between seven and twelve unique sets of beach ridges with each set containing a different number of individual ridges (Missimer, 1973b). Figure 6 shows the location of all defined beach ridge sets with the truncation lines being the outer boundaries. The individual beach ridges within each set are subparallel, but ridge orientation between sets is different (See Figure 7). There are systematic variations in relative altitude of individual ridges within each set and there are relative differences between sets. The above-mentioned concepts are very important because: (1) the primary sediment fabric is parallel to the beach ridges in each set and permeability is related to sediment fabric; (2) variations in land surface altitude control

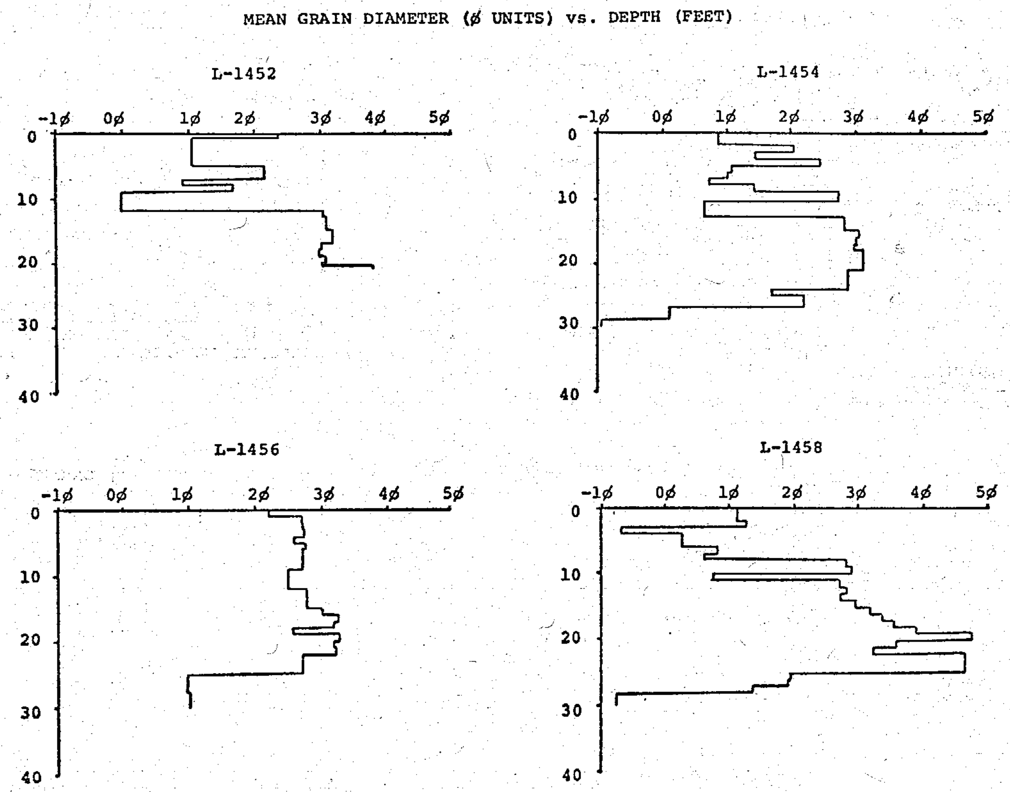


Fig. 5 - Diagram showing variation in mean grain diameter of the sediment with depth. (from Missimer, 1973a).

surface water drainage to a certain degree. These concepts will be discussed in more detail later in the report.

A more rigorous and complete discussion of the geology, age, and origin of Sanibel Island is given in Missimer (1973a) and Riggs (1976).

Ground-water System

DEEP ARTESIAN AQUIFERS

There are at least two deep aquifers underlying Sanibel Island that yield significant quantities of water. These zones are termed the lower Hawthorn aquifer and the Suwannee aquifer (Sproul and others, 1972). Both aquifers are artesian or confined from the overlying shallow ground-water and surface-water systems. Hence, neither aquifer is directly recharged on the island.

The only information presently available on the geology of the lower artesian aquifer system comes from a test hole made by the Island Water Association (L-1533) and various logs made by the U.S. Geological Survey of existing wells. The lower Hawthorn aquifer is

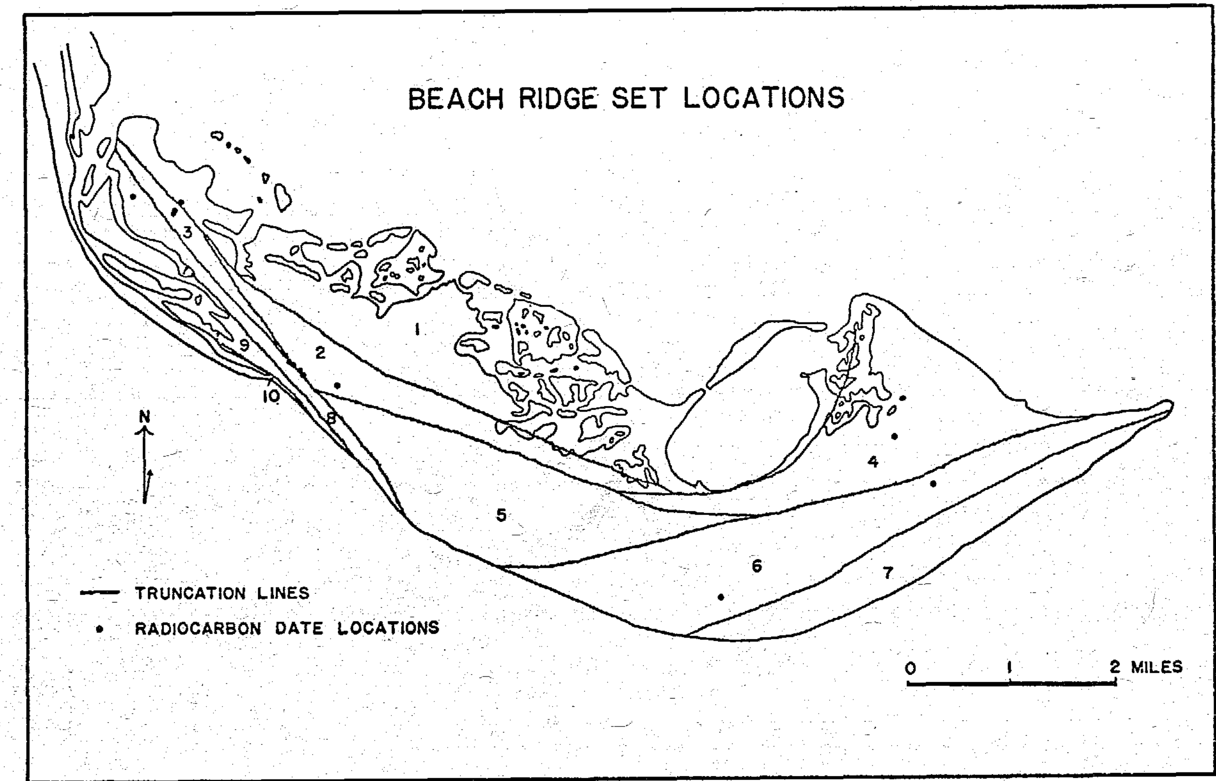


Fig. 6 - Map showing beach ridge set locations on Sanibel Island. (from Missimer, 1973a).

positioned near the contact between the Hawthorn Formation and the underlying Tampa Limestone, while the Suwannee aquifer lies near the contact between the Tampa Limestone and the underlying Suwannee Limestone (Figure 8). It is not known whether these zones are hydraulically connected because of the lack of detailed geologic data (See previous section).

Water Levels. Artesian head pressure within the lower aquifers ranges from 16 to 32 feet above mean sea level on the island. The highest head occurs on the eastern part of the island and decreases to the west. It is not known what season ranges in head occur on the island, but daily fluctuations of one to two feet occur due to tidal and atmospheric variations (Boggess, 1974a).

The head pressures measured on Sanibel generally fit the pattern established by Boggess (1974b) for Lee County. Local deviations from the regional pattern as seen on the island are the probable result of leakage of water out of corroded or damaged well casing into overlying aquifers, pumpage, or discharge of "wild" flowing wells. The county-wide potentiometric surface for the lower Hawthorn and Suwannee aquifers shows a decline in artesian pressure has occurred over large areas during the past 20 years and recharge to the system comes from outside Lee County (See Figure 9). Since water flows perpendicular to the potentiometric contours, it is suggested that the recharge area for the system lies somewhere to the northeast, possibly in Highlands County or further north, but the exact area is not known.

Water Quality. The lower Hawthorn and Suwannee aquifers generally contain saline water or water that by definition has at least 1,000 milligrams per liter (mg/l) of dissolved solids (Krieger and others, 1957). Vertical change in water quality within the saline water aquifers in test well L-1533 is shown in Figure 8. Dissolved chloride concentration is used for comparison instead of dissolved solids. The relationship between these parameters is given in Figure 10. It should be noted that the water in the upper part of the lower Hawthorn aquifer is highly saline or contains dissolved solids in excess of 10,000 mg/l. A relatively thin zone of "fresh" water, containing 600 mg/l to 1000 mg/l of dissolved chloride, occurs near the base of the lower Hawthorn aquifer. Dissolved chloride concentrations in the Suwannee aquifer are nearly 1000 mg/l at the top of the aquifer and increase progressively with depth.

Extreme variation of water quality in each aquifer occurs from well to well on the island. The "fresh" water zone occurs at different depth intervals in nearly every well and sometimes does not occur at all.

General Discussion. Little is known about the characteristics of each aquifer, such as transmissivity and storage coefficient. No standard multi-well pump test has been made to give the necessary information on sustained yield, drawdown, and permanence of quality.

At least 40 deep artesian wells exist on Sanibel Island. Many of these wells are not properly constructed and are probably leaking poor quality water into fresher zones as described in other areas of Lee County by Sproul and others (1972). Some deep artesian wells are discharging water wildly at land surface and in some cases contaminating the water table aquifer.

The City of Sanibel takes its municipal water supply from the "fresh" water zone in the lower Hawthorn aquifer. Even though the city uses an electrodialysis

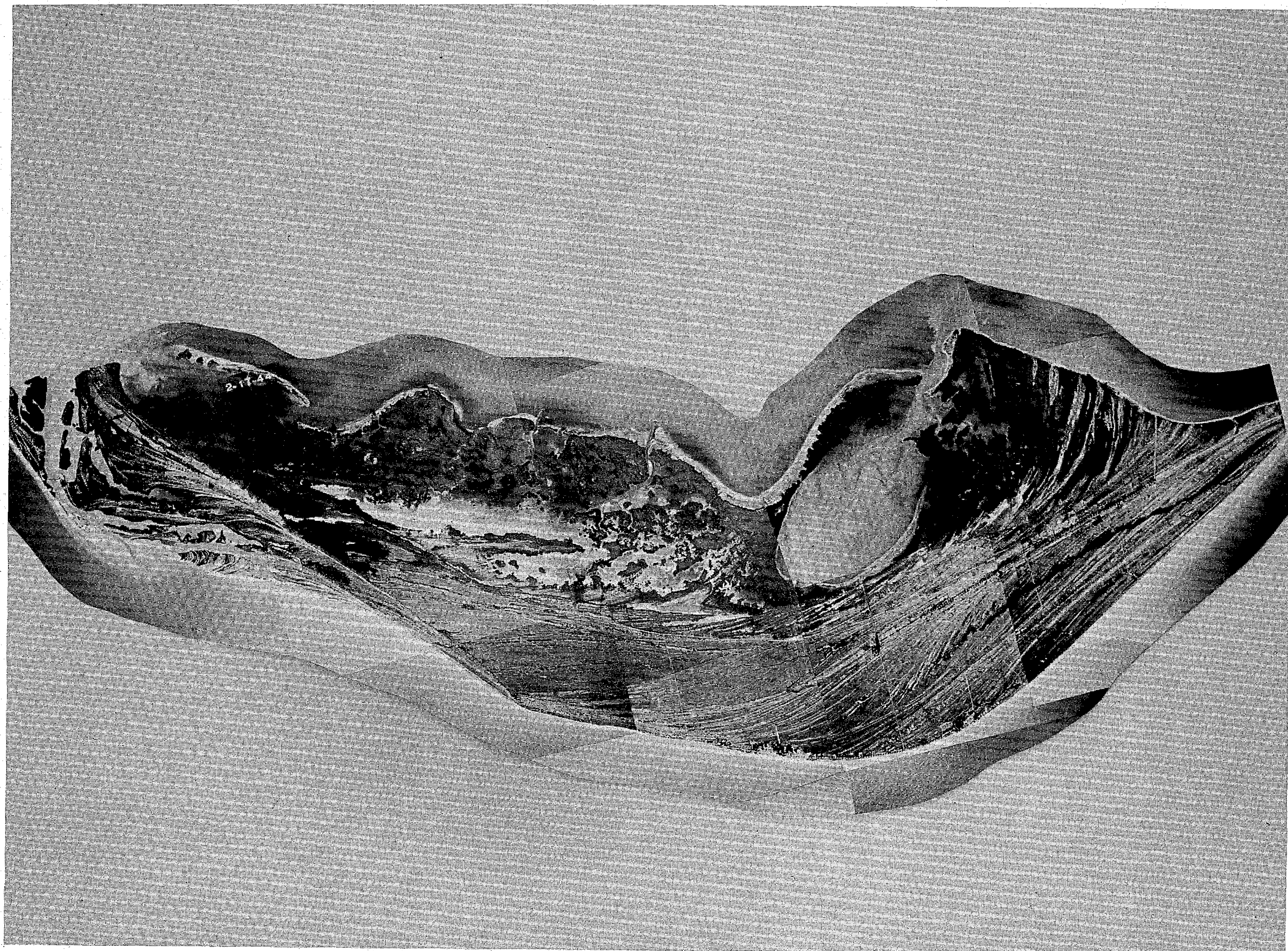


Fig. 7 - Aerial photo of Sanibel Island showing individual beach ridges as visible in 1944.

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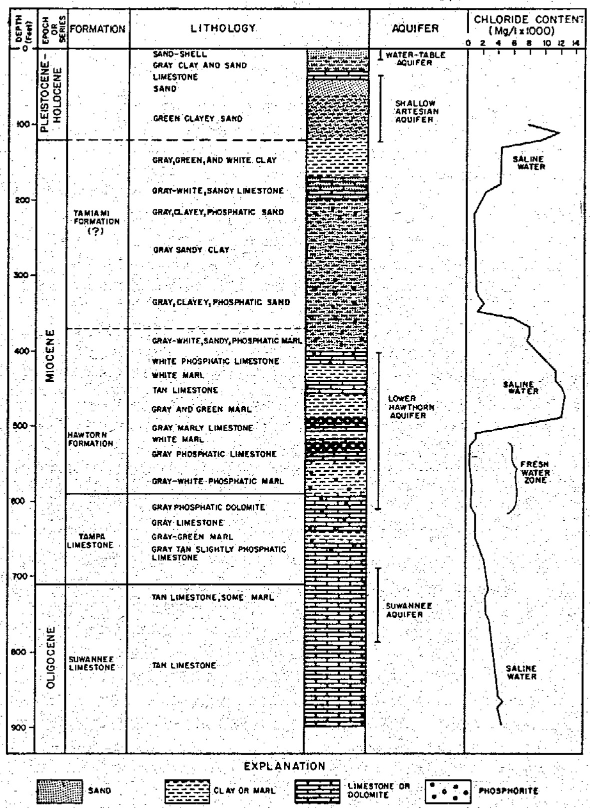

Fig. 8 - Log showing the geologic formations, lithology, aquifers, and chloride concentrations in water from test hole L-1533. (from Boggess, 1974a).

desalination system for water processing, it is extremely hazardous to design a well field without adequate knowledge of the aquifer properties. It is not known whether a sustained yield of adequate quality water can be maintained over a long time period so as to keep the system functional. The problem is probably not one involving quantity of water, but one involving quality of water. With highly saline water above, below, and on several sides of the production zones, the system can expect future problems. It is possible that a decline in head could initiate migration of highly saline water like what has happened at McGregor Isles or other areas of Lee County (Sproul and others, 1972).

Most of the information contained in this discussion comes from Boggess (1974a) and Boggess (1974b).

SHALLOW ARTESIAN AQUIFER

Numerous observation wells have been driven into the upper part of the Pleistocene limestone (See page 176), which forms the shallow artesian aquifer beneath the island. The top of this aquifer occurs between 25 to 30 feet below mean sea level (Figure 11). Locations of the borings from which the stratigraphic and hydrologic data in Figure 11 were derived are given in Figure 12.

The shallow artesian aquifer is normally confined from the overlying water-table aquifer by a previously described heterogeneous mud stratum and is confined from the lower artesian aquifers by carbonate clay beds in the Tamiami Formation. There are some areas where the upper confining bed is extremely thin, sandy, or nonexistent. Interaquifer leakage between the shallow artesian and the water-table aquifers is possible in these areas.

Water Levels. Water levels in the shallow artesian aquifer fluctuate with the tides on a daily basis. The range of tidal water level fluctuations in the aquifer is a function of distance to the nearest tidal water body and the permeability of the aquifer. Hence, the lowest tidal efficiencies usually occur near the middle of the island and the highest adjacent to the shorelines. Also, the greater the distance from the tidal water body, then the greater is the time lag between a given tidal change and the corresponding water level change in the aquifer. Figure 13 shows water level fluctuations in well L-1408 as compared to tidal fluctuations recorded at Point Ybel. Note the similarities and the slight time lag. Water levels in the shallow artesian aquifer are not greatly responsive to seasonal water level variations in the overlying water-table aquifer.

Water Quality. Water quality varies considerably in the shallow artesian aquifer. Dissolved chloride concentrations range from 2,250 mg/l to 30,900 mg/l with numerous intermediate values (Figure 14). The high chloride values exceed concentrations in seawater which usually run about 19,000 mg/l in the vicinity of Sanibel. These high chloride waters may have formed when the strata were originally deposited or concentration may have occurred through downward leakage and selective osmotic differentiation. The lower chloride concentrations may be the result of partial flushing during deposition or modern flushing.

General Discussion. There is no known recharge to the shallow artesian aquifer other than possible downward leakage, which occurs only under special conditions. Leakage of water between the shallow artesian aquifer and the water-table aquifer is strictly a function of head differential and vertical permeability. During high tide periods the water level in the shallow artesian aquifer usually stands above the water table and potential leakage is upward. During the low part of the tidal cycle, the water level in the shallow artesian aquifer usually drops below the water table and potential leakage is downward (See Figure 15). When the water table is high for an extended period, such as after heavy rainfall, the water table may remain above the artesian water level through numerous tidal cycles.

Leakage between the two shallow aquifers is dynamic -- it is continuously occurring to some degree. However, only the net quantity of water leaked up or down has any significance. Since vertical permeability also controls the quantity of water leaked, along with head differential, it is important that the mud stratum be preserved so as not to enhance vertical water movement that would degrade water quality in the water-table aquifer.

The information contained in this portion of the report comes from Boggess (1974a) and analysis of data recently collected by the U.S. Geological Survey.

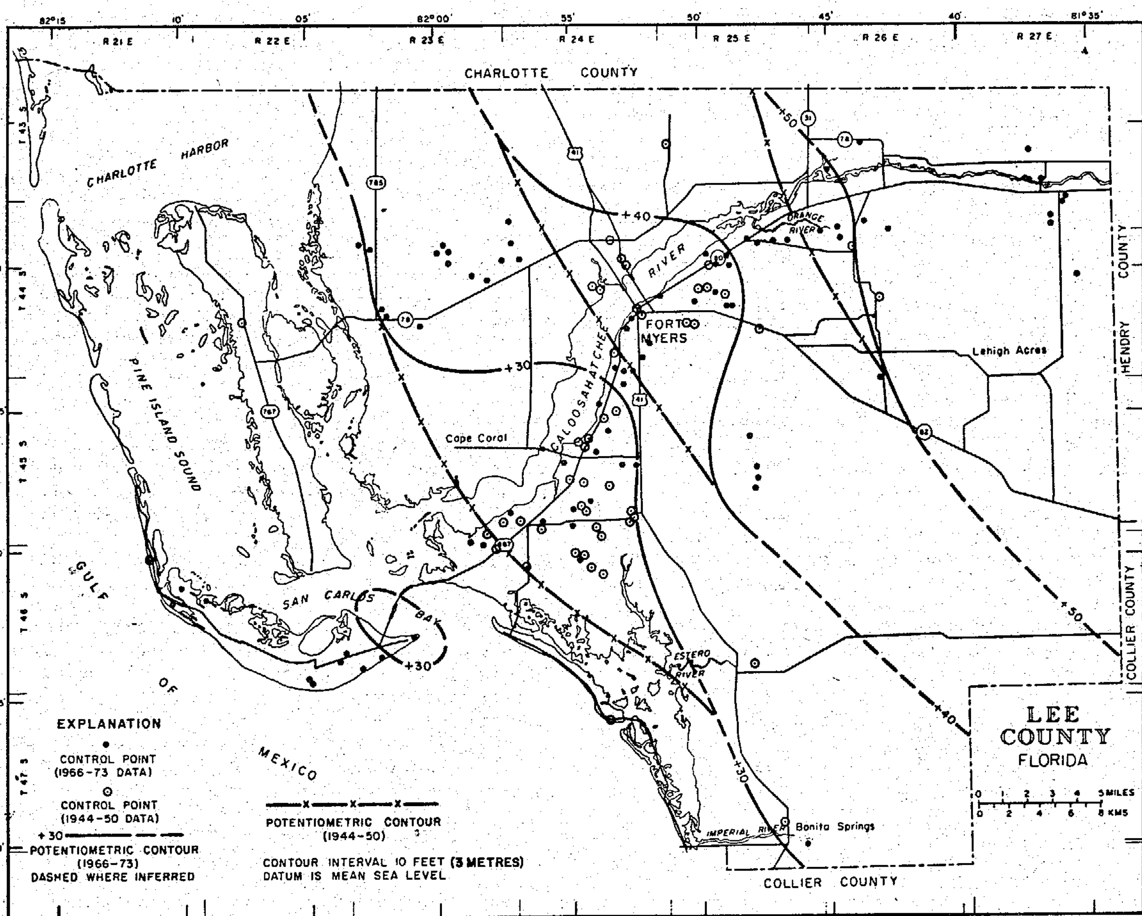

Fig. 9 - Potentiometric surface of the lower Hawthorn and Suwannee aquifers in Lee County 1966-73 and 1944-50. (from Boggess, 1974b)

WATER-TABLE AQUIFER

Unconfined water at shallow depths beneath land surface is divided into two zones: the unsaturated zone in which air and water exist in variable proportions, and the saturated zone in which water fills all of the pore space. When water enters the ground-water system at land surface, it passes through several subzones in the unsaturated zone before reaching the saturated zone (Figure 16). The soil water, intermediate soil water, and capillary fringe water subzones all have important roles in controlling both entry and exit of water from the aquifer at land surface. The upper surface of the saturated zone, the water table, is defined as "that surface in an unconfined water body at which pressure is atmospheric" (Lohman and others, 1972).

On Sanibel Island the uppermost 20 to 25 feet of sediment is unconfined and consists of quartz sand, shell and some minor percentages of carbonate mud in the lower beds (See page 170). The saturated part of this sequence is termed the water-table aquifer (Figure 7).

Water Levels. Water table fluctuations on Sanibel Island are controlled primarily by climatic factors with secondary effects caused by man's activities. The water table rises in response to recharge and declines when water is discharged from the aquifer. The only natural source of freshwater recharge on the island is rainfall. Figure 17 shows the relationship between monthly rainfall and position of the water table in well L-1403. In the absence of freshwater recharge, saline water may recharge the aquifer laterally from the sea, through the surface water system, or from the underlying shallow artesian aquifer (See page 180). Natural discharge from the aquifer includes evaporation, evapotranspiration, groundwater discharge to the sea, and discharge to streams or lakes. Some recharge to the aquifer is the result of man's activities, such as inflow from deep artesian wells, inflow of treated sewage effluent, and septic tank discharges into the aquifer. Discharge from the aquifer has also been altered by man in that the enhanced surface drainage system now discharges some water to the sea and a minor amount of water is pumped for irrigation. The range in water table position varies from year to year based on variations in recharge and discharge.

The position of the water table represents the quantity of water in storage in the ground. When the water table is high in Sanibel, a much greater quantity of fresh water is stored and the wetland areas are filled with surface water. When the water table is low, the quantity of water in storage is decreased and wetland areas tend to dry. The highest and lowest recorded positions of the water table are shown in Figure 18 and a theoretical cross-section of the island showing the high and low positions of the water table is shown in Figure 19. Note that the water table in the interior part of the island often drops below mean sea level during the dry season.

Altered Discharge. Construction of canals and drainage ditches has had a pronounced effect upon the position of the water table over large areas of

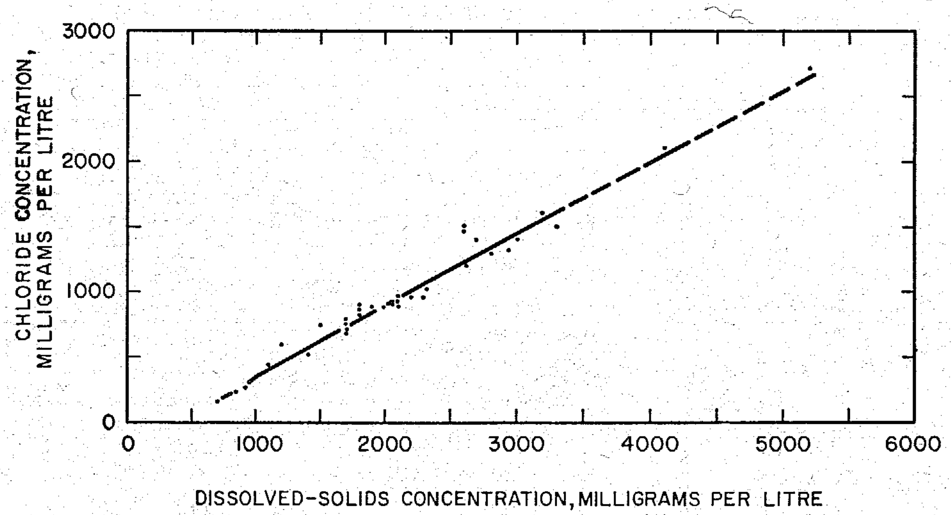

Fig. 10 - Relation between dissolved chloride and dissolved solids in water from the lower Hawthorn and Suwannee aquifers. (from Boggess, 1974b).

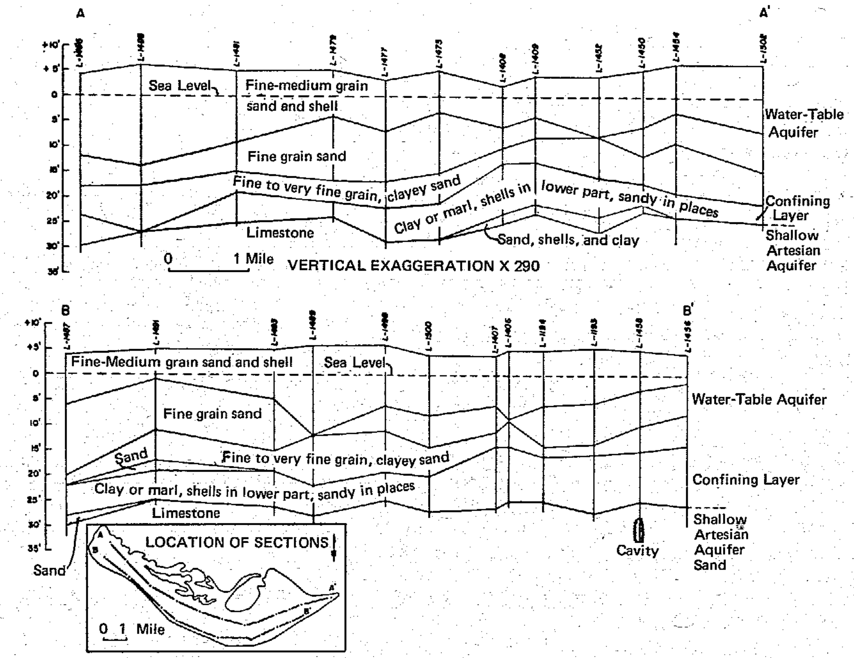

Fig. 11 - Diagram showing the position of the shallow artesian aquifer and the position and thickness of the water-table aquifer. (from Boggess, 1974a).

the island. The deep tidal canals at the eastern end of the island have permanently lowered the water table. An example of the effects of a drainage canal on the water table, located in another part of Lee County, is given in Figure 20. A drainage canal was constructed during 1971 about one mile from the observation well. As can be seen, the water table has been permanently lowered several feet and storage has been depleted (See Missimer and Boggess, 1974). The deep tidal canals have been spaced so closely on some parts of the island that the water table probably does not range much above sea level.

The altered interior drainage system--the Sanibel River and connected ditches and canals--has caused a more rapid recession of water levels during the dry season than previously existed (comparison of Provost data and Boggess data). The control structures at Tarpon Bay and at Beach Road are not adequate and leak water both in and out. Evaporation losses have also been increased by the additional amount of atmospherically exposed surface water. All of the recharge and discharge factors will be discussed in more detail on page 185.

Water Quality. Quality of water varies considerably in the water-table aquifer. Dissolved chloride concentrations range from mg/l in well L-1401 to 23,200 mg/l in well L-1516 (Boggess, 1974a). The areal distribution of chloride in the aquifer is related to proximity to tidal seawater and net vertical leakage. High chloride waters tend to occur in the low-lying areas and lower chloride waters in the upland areas.

Chloride concentrations in the water-table aquifer generally increase with depth throughout the island (Figure 21). The chloride concentration varies with time because of variations in recharge and discharge from the aquifer. A relatively small quantity of potable water exists in the aquifer on an annual basis. In reality, only the upper portion of the aquifer contains any significant quantity of water with less than 1,000 mg/l of dissolved solids.

High chloride water exists in parts

of the aquifer. This water contains chloride concentrations in excess of 19,000 mg/l, which is the approximate seawater concentration in the vicinity. Boggess (1974a) has suggested that the high chloride waters indicated the presence of evaporite beds. It is the opinion of the author that the high chloride water is the result of a combination of the following factors: tidal overtopping, selective uptake of water by plants (ion exclusion), and concentration by evaporation of water in the sands, such as described by Hellwig (1974). The relative high density of the water and the low flow gradients keep the water in place and tend to cause continued concentration.

Precise properties of the water-table aquifer have not been measured on Sanibel Island. However, using the grain size data given by Missimer (1973a), values of storage coefficient and permeability can be estimated. Because the mean grain diameter (Figure 7) and the degree of sorting decreases with depth (Missimer (1973a), the storage coefficient also decreases with depth. A storage coefficient of about 0.3 is estimated for the upper sands and shell and a storage coefficient of about 0.15 is estimated for the lower sands. An average of 0.23 is estimated for the entire aquifer thickness on Sanibel. The coefficient of permeability also decreases with decreasing mean grain diameter. Using the method of Fair and Hatch (1933), a gross estimate of the coefficient of permeability is calculated at 900 gallons/day/foot. Some special observations about permeability should be noted: permeability estimates of the upper sediments in the aquifer vary between 800 and 2,000 gallons/day/foot with values parallel to the sediment fabric probably much greater than perpendicular to it (See page 170); permeability estimates in the lower part of the aquifer range from 90 to 500 gallons/day/foot; horizontal permeability is probably much greater than vertical permeability because of vertical variation in grain size, composition differences, and sediment fabric.

Transmissivity is estimated by multiplying the average aquifer thickness, approximately 15 feet, by the permeability, 900 gallons/day/foot. The calculation yields a value of 13,500 gallons/day/foot. This value is only an estimate of the average for the entire aquifer. It probably varies more than 100 percent from area to area.

General Discussion. It has recently been suggested that some municipal use be made of the "fresh" water in storage in the aquifer. This practice would be an extremely unwise procedure because of the natural variation in water quality. Even a relatively small amount of pumping of "fresh" water from the upper part of the aquifer would probably cause upward movement (pluming effect) of the saline water that exists at the base of the aquifer. Tidal overtopping could cause such a system to fail and the impact of such a system could further alter the hydrologic system.

In summary, without an adequate quantity of water in storage within the water-table aquifer, the present flora and fauna on Sanibel Island could not exist.

Surface Water System

Few barrier islands in the world have developed any natural type of channelized or partially channelized interior drainage system. The reason that a surface drainage system does not usually develop on most barrier islands is that the sediment, generally sand or gravel, allows nearly instantaneous infiltration of precipitation because of high rates of vertical permeability.

Sanibel Island is different in that a partially channelized interior drainage system, the Sanibel Slough, developed rather late in its geologic history. Beach ridge geometry, variable permeability, and vegetation patterns all contributed to the formation of the Sanibel Slough at some time during the last 1000 to 1500 years of the island's 5000-year history. The slough meandered almost exclusively through beach ridge sets 5 and 6 (Figure 6) over an irregular course nearly 8 miles long. Two "mini-basins" were formed by segments of the slough with the western segment in beach ridge set 5 being separated by some low beach

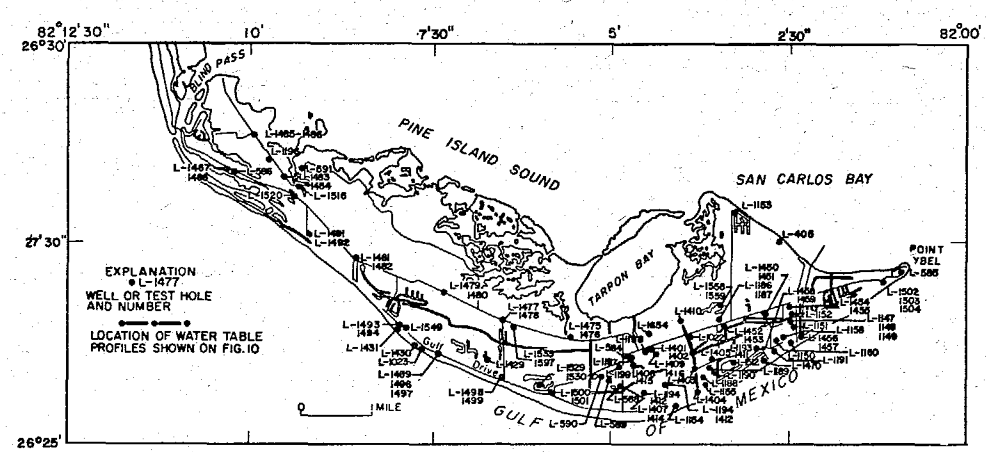

Fig. 12 - Map showing the location of wells, observation wells, and test borings on Sanibel Island. (from Boggess, 1974a).

ridges south of Tarpon Bay from the eastern segment lying in ridge set 6. The system was only unified during high water stages.

The drainage characteristics of the eastern "mini-basin" differed considerably from the western "mini-basin." In the east, the "course" of the Sanibel Slough was straighter, although it transected most of the low ridges in the set at oblique angles (Figure 7). The only "tributaries" to the slough in the east were the natural swales transected by the slough. During flow conditions, water in the eastern "basin" moved to the east and during high water conditions it broke through ridge set 7 and discharged into the Gulf of Mexico just west of Point Ybel. In the west, the slough meandered considerably because of the low relief of the ridges in set 5. There were several "branches" to the slough. During flow conditions, water flowed to the west and during high water, it broke through ridge set 8 and discharged into the Gulf at a point about 2.5 miles east of the Blind Pass Bridge.

The Sanibel Slough was only a drainage-way and never a true stream. Flow only occurred during times when the water table was high and infiltration of precipitation was inhibited. The "break-out" phenomena of drainage into the Gulf was a rare event and was not as catastrophic as implied by Provost (1953). During times of normal or moderately low water condition, water remained in groundwater storage in sets 5 and 6. The low-lying part of these beach ridge sets was, and still is, the interior wetlands.

PRESENT INTERIOR DRAINAGE SYSTEM

In the past 20 years, the natural drainage system of Sanibel Island has been channelized and expanded for a number of reasons. The former "course" of the Sanibel Slough was modified, deepened, and widened. A network of canals and ditches was connected to it. The eastern "mini-basin" was terminated by a series of deep tidal canals at Beach Road, where a water level control structure was constructed. The western "mini-basin" was extensively

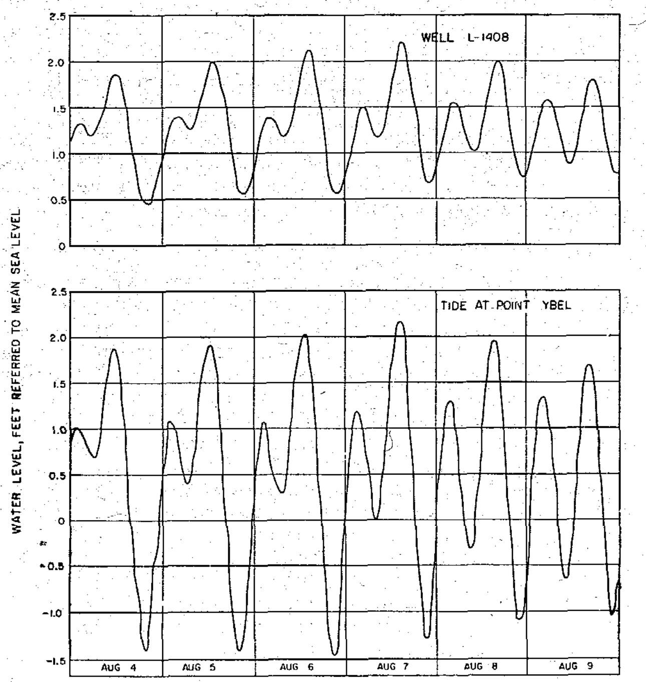

Fig. 13 - Diagram showing records from the tide gauge at Point Ibel and well L-1408, August 4-9, 1971. (from Boggess,1974a).

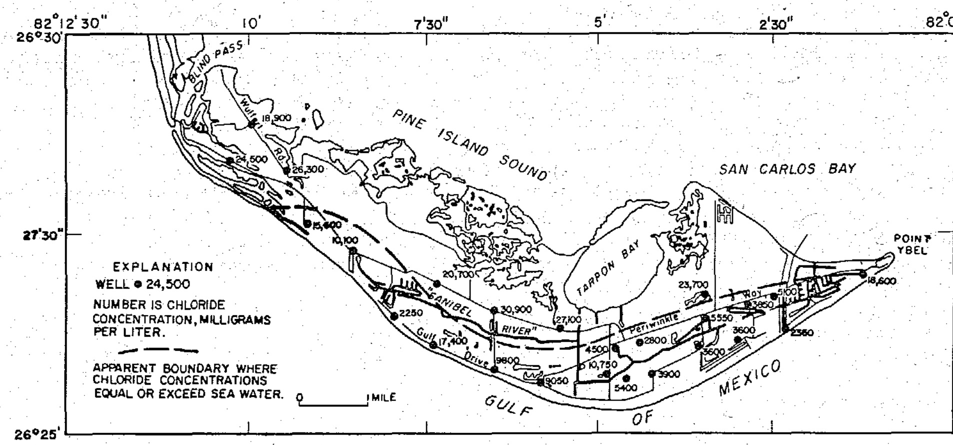

Fig. 14 - Map showing chloride concentrations in water from the top of the shallow artesian aquifer on Sanibel Island.

ditched and the flow direction was reversed so that discharge occurs at Tarpon Bay through a control structure. During high water conditions, water still will "break-out" at the western part of the island (See page 177). Roads cross the channel at several locations. Because the small culverts that run beneath the roads do not provide adequate connections, the system is now segmented. During high water conditions, interior flooding sometimes occurs because of the undersized culverts.

STAGE AND FLOW

Water rarely discharges through the surface-water system of Sanibel Island. Sufficient rainfall must accumulate so as to raise the stage above 2.5 feet above mean sea level before discharge can occur at the control structures. According to U.S. Geological Survey stage data collected upstream of the Beach Road control structure, a sustained 2.5-foot stage was only attained twice, September-October, 1971 and June-July, 1974, since November, 1970 (Figure 22). During the two discharge periods, significant quantities of water flowed through the control structures. Boggess (1974) estimated that during the storm of September, 1971, about 500 million gallons of water flowed into Tarpon Bay and about 100 million gallons discharged at Beach Road. Some minor discharge has occurred numerous times during the wet season because of leakage at both control structures and because of tampering at the Beach Road control.

The present drainage system of Sanibel Island has had a pronounced effect on the water-table aquifer (See page 175). Since the canals and ditches are dug through very permeable sand and shell, water in the water-table aquifer flows rapidly out of the aquifer and into the adjacent canal when there is a positive gradient. This discharge out of the ground-water system has increased the rate of recession during the dry season and has caused temporary depletion of storage in the aquifer (shortened the hydroperiod). Hence, the stage of the surface-water system should be maintained at the highest possible level. Also, in order to maintain the surface-water stage during the dry season, the total surface area of canals and ditches should be minimized so as to prevent excess evaporation losses.

The present controlled water stage of 2.5 feet at each control structure is the highest practical level at those respective localities. If a higher stage were maintained, extensive flooding of low lying upstream areas would occur. In parts of the interior wetlands area, as defined by Johnson Engineering (1975), a water level of about 3.0 feet could possibly be maintained if more control structures and outflow barriers were installed. Such a project would require a large scale investigation of water impoundment techniques applicable to Sanibel Island. It is the opinion of the author that even if the surface-water stage were maintained at 3.0 feet during the wet season, the recession of the water table would still reach low levels similar to present, but the added storage would slow the rate of recession. Hence, the hydroperiod would be extended with enhanced environmental conditions for the flora and fauna. The extended hydroperiod would probably increase the biomass of the vegetation.

WATER QUALITY

Water quality in the Sanibel River and other parts of the interior drainage system varies considerably. The salinity of the water in any particular segment of the system is controlled by climatic factors, proximity to a source of saline water leakage, the natural quality of water in adjacent parts of the water-table aquifer, and the channel characteristics of the drainageway. Heavy nutrient influx, stagnation, and deposition of organic detritus all degrade the general quality of the water (Missimer, 1975).

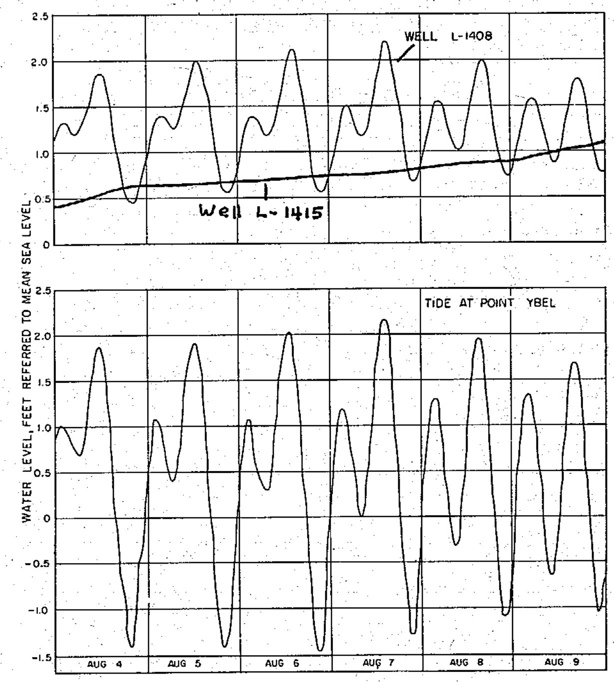

Fig. 15 - Diagram showing record from well L-1408 in the shallow artesian aquifer with superimposed record from well L-1415 in the water-table aquifer.

Dissolved chloride concentration varies seasonally with recharge and discharge. In most parts of the surface-water system, chlorides decrease during the wet season as a result of flushing and dilution by rainfall. In some parts of the Sanibel River high chloride water at the channel bottom is trapped because of bottom irregularities (See Johnson Engineering, 1975). The trapped water decreases in chlorides only by dilution, but the dense water mass only flushes during high water periods. Chlorides increase during the dry season because evaporation and evapotranspiration losses tend to cause concentration of dissolved solids.

The greatest source of saline water entering the Sanibel River is seawater that leaks into the system at the two control structures. Whenever the tide rises above 2.5 feet mean sea level, seawater enters the system directly. During the dry season as the freshwater head in the interior declines, leakage occurs through the structures almost continuously. The leakage phenomena is illustrated in Figures 23 and 24, in which the seasonal fluctuations in chloride concentration are shown at the top and bottom of sites located upstream of the Beach Road and Tarpon Bay controls, respectively. Note the high bottom chlorides. After the denser seawater leaks through the structures, it migrates a considerable distance upstream as a density current. As the surface-water head declines, the high chloride water migrates further

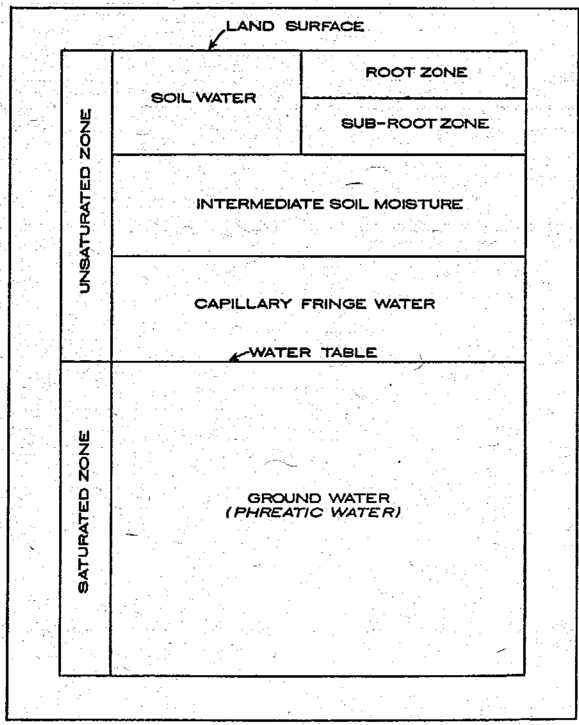

Fig. 16 - Diagram showing divisions of subsurface water. (From Missimer and Boggess, 1974).

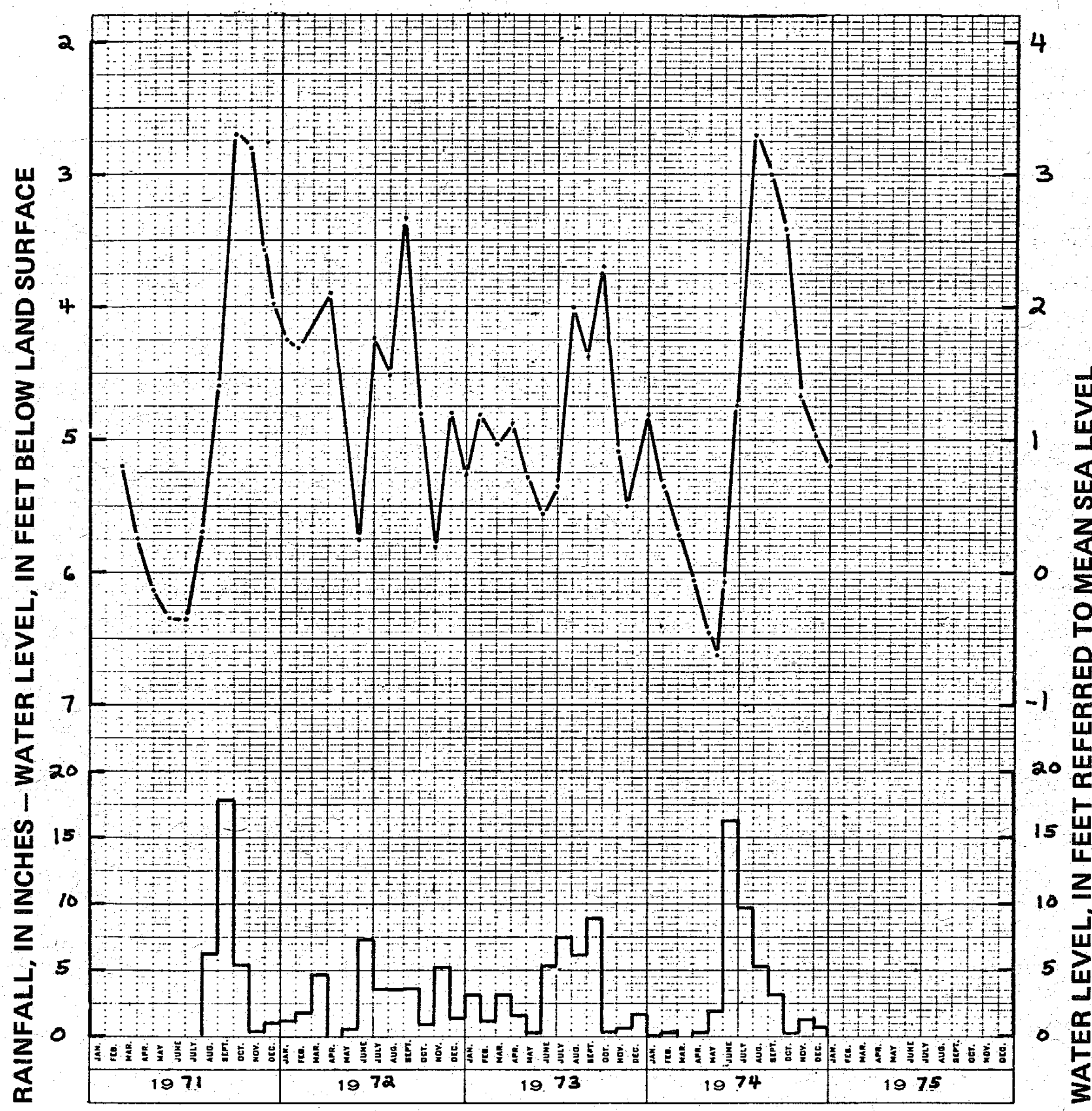

Fig. 17 - Hydrograph of well L-1403 and monthly rainfall at station 2 on Sanibel Island, February 1971-December, 1974.

upstream. Under certain conditions, such as during high winds, the density stratification can be disturbed and mixing occurs, which leaves the entire water column salty (See Boggess, 1974a).

Where deep artesian wells discharge saline water into the interior drainage system, dissolved chlorides increase significantly. For example, Boggess (1974a) showed that continuous discharge of water, containing a chloride concentration of 5,850 mg/l from well L-1472, raised the dissolved chloride concentration in the Sanibel River in October, 1971. The well was capped in late October, 1971 and the effects dissipated by the end of November, 1971.

Heavy influx of nutrient-laden wastewater into the eastern segment of the Sanibel River has caused blooms of undesirable vegetation and has helped deplete dissolved oxygen (Missimer, 1975). General stagnation of the water and the deposition of organic detritus has caused low values of dissolved oxygen to occur throughout much of the interior drainage system.

During hurricane conditions, when tidal overtopping occurs, the seawater which enters the interior drainage system could take years to flus because of poor channel connections. Most of this dense water accumulates at the base of the water-table aquifer.

The present state of the Sanibel River should be modified in order to improve environmental quality. If the interior salinity were to rise above ten parts per thousand for extended time periods, extensive vegetation changes could result (Tabb and Manning, 1961). To improve the system, the bottom irregularities should be eliminated in the main channels of the Sanibel River and bottom gradients should be established. The culverts at road crossings should be improved. The control structures at the ends of the system should be properly reconstructed. Accumulated organic detritus should be removed from the bottom of the drainageways and the new system be designed so as to allow oxidation of any deposited organic materials. Treated sewerage effluent should not be permitted to enter the system. A study should be made of impoundments of water in the interior wetlands.

PONDS, REAL ESTATE LAKES, EXCAVATIONS

Many ponds, lakes, and canals have been excavated on Sanibel Island during the past 10 years. These excavations were dug mostly to obtain fill material in order to raise the level of the surrounding land surface for the purpose of meeting housing regulations and to obtain septic tank permits.

These excavations have had pronounced effects upon the water-table aquifer both in the construction phase and after completion. Several of the lakes and canals were dug too deep and part or all of the confining mud stratum was removed, hence, permitting upward leakage of high chloride water from the shallow artesian aquifer into the water-table aquifer. During excavation of several ponds, a dewatering process was used (pumping) which caused wide dispersion of high chloride water pumped

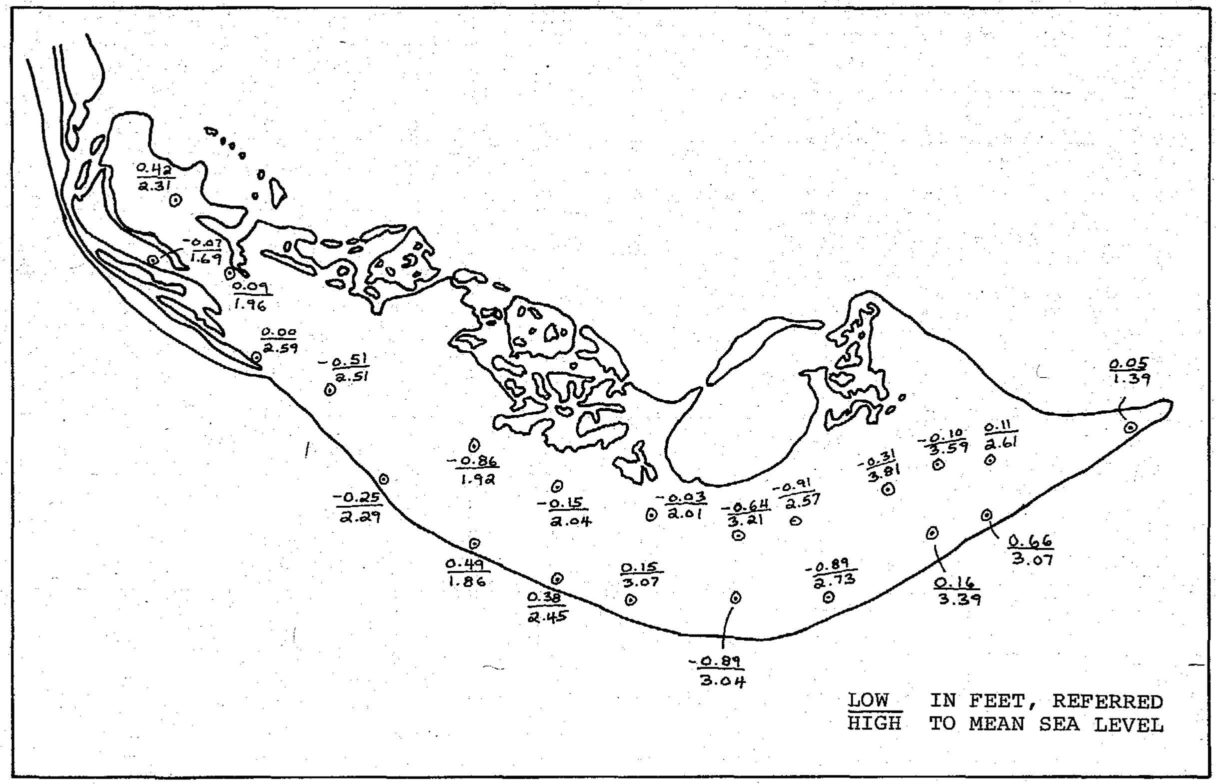

Fig. 18 - Highest and lowest positions of the water table on Sanibel Island.

from the lower part of the water-table aquifer. The pumping stress could also have caused upward leakage of saline water from the shallow artesian aquifer. All of the lakes now provide a free water surface which facilitates evaporation of water and causes the water table in adjacent areas to recede at more rapid rates than in the past. The finished lakes now act as accumulation basins for highly saline water, septic waste, and organic detritus. Depressed oxygen conditions prevail in many of the excavations and lakes (Missimer, 1975).

Lakes and excavations of any type should be limited in depth so as to prevent saline water leakage from below and to allow sufficient concentrations of dissolved oxygen in the water column to prevent accumulation of organics at the bottom (enough to oxidize the organics). Perhaps a reasonable depth limitation would be five feet below mean sea level for any excavation on the island. More data on lakes, ponds, and excavations on Sanibel are given in Boggess (1974a) and Missimer (1975).

In summary, the concept of the real estate lake on Sanibel can work if proper water quality criteria are used in their design. The lakes can be larger, shallower, and oriented in consideration of wind stress to enhance oxygenation of the water.

Saline Water Intrusion

Since Sanibel is an island, it is surrounded by seawater on all sides. Highly saline water directly underlies the island in the shallow artesian aquifer and in several deeper artesian aquifers. Hence, the "fresh" water part of the water-table aquifer is delicately positioned and is in constant danger of being intruded by highly saline water. There are basically six ways in which highly saline water can intrude the "fresh" water areas: 1) density intrusion of water directly from the sea into the water-table aquifer (Ghyben-Herzberg intrusion), 2) leakage or intrusion of highly saline water into the interior surface-and ground-water systems through uncontrolled or poorly controlled canals that are connected to tidal water bodies, 3) massive intrusion of highly saline water of all or parts of the island during tidal overtopping caused by intense storms, 4) upward leakage from the underlying shallow artesian aquifer, 5) discharge of highly saline water at the surface through improperly constructed, damaged, or uncontrolled deep artesian wells, and 6) pumping and dispersing of highly saline water into interior parts of the system.

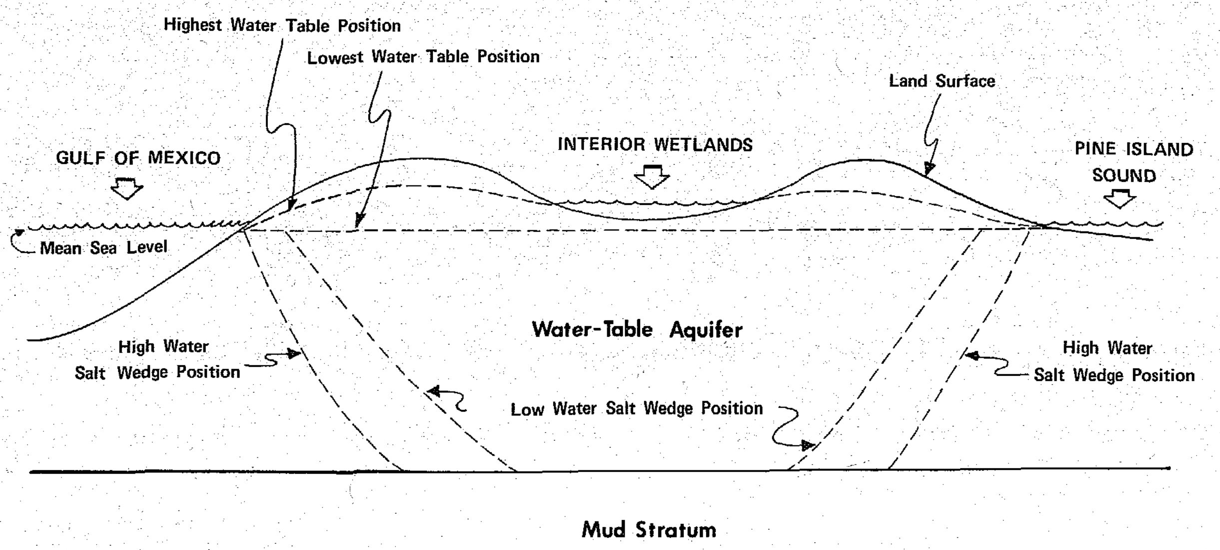

Fig. 19 - Diagram showing the theoretical position of the water table across Sanibel Island during high and low water table positions.

DENSITY OR GHYBEN-HERZBERG INTRUSION

Along the shoreline of Sanibel, the water-table aquifer comes in direct contact with seawater. Since seawater is denser than freshwater, it tends to sink to the base of the water-table aquifer and forms a wedge (See Badon Ghyben, 1888-89; Herzberg, 1901; Todd, 1953).

The position and geometry of the saltwater wedge along the coast of Sanibel is controlled by the water density contrast, permeability of the water-table aquifer, and the level or head of fresh water in the aquifer. Since the water-table aquifer is underlain by less permeable muds, the intrusion of seawater is mostly horizontal. Because water levels in the water-table aquifer fluctuate with seasonal variations in recharge and discharge, the position of the waltwater wedge also fluctuates. When interior water levels are high, the seawater is forced outward and when water levels are low, the wedge moves toward the interior of the island.

Seawater does not usually intrude more than about 500 feet inland from the Gulf under natural conditions even during very dry periods when the water table is low (only available data comes from the western Gulf Drive area). The reasons that the intrusion is not very great are: the aquifer is only about fifteen to twenty feet thick, the intruding seawater must pass across the alignment of the sediment fabric, and the base of the water-table aquifer already contains saline water, which causes a minimal density contrast. There are few available data on this type of intrusion on Sanibel. Vertically, nothing is known about the ranges and effects of lateral seawater migration along the northern shore of the island.

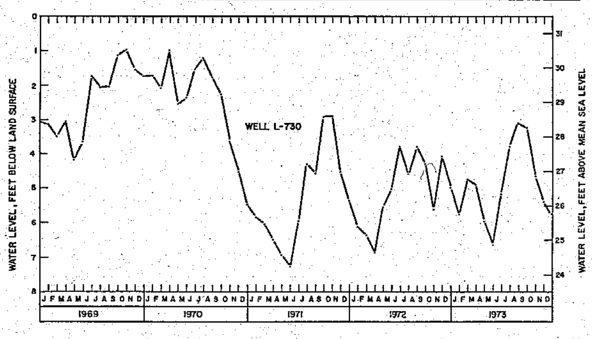

Fig. 20 - Hydrograph of well L-730, 1969-73. (from Missimer and Boggess, 1974).

INTRUSION THROUGH CANALS

Saline water intrusion is facilitated by the construction of uncontrolled tidal canals (Figure 25). On the eastern part of Sanibel, several large canals were cut well below mean sea level almost entirely across the island. The water-table aquifer in the vicinity of this area probably no longer contains any freshwater. Once the highly saline water enters the water-table aquifer, it is extremely difficult to flush it out because of the low water table gradient.

The two control structures at the ends of the Sanibel River also allow intrusion of highly saline water into the interior (See page 178).

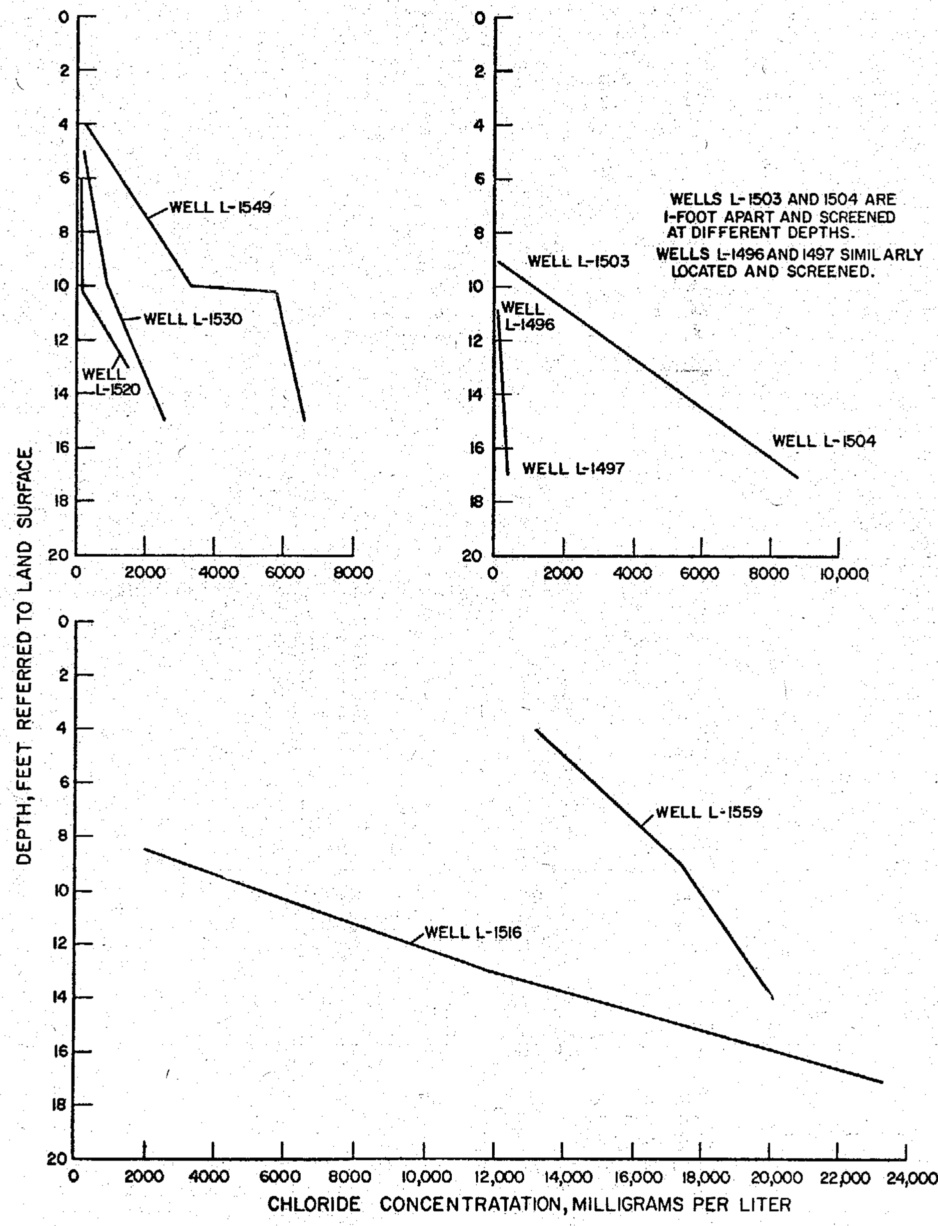

Fig. 21 - Graphs showing increase in chloride content of water with depth in the water-table aquifer.

The structures are frequently overtopped during high tides, and leakage occurs through them during most of the dry season.

TIDAL OVERTOPPING

All or part of the island is periodically flooded by seawater during severe storms. Some of the intruded seawater is flushed out during the storm, but large volumes enter the surface-and ground-water systems on the island. Since the highly saline water is denser than fresh water, it tends to sink to the lowest points in either system. Much of the dense water is trapped in bottom lows in the Sanibel River channels, lake bottoms, and at the base of the water-table aquifer. It generally remains in place and is slowly diluted. No data has been collected immediately after a major tidal flood on Sanibel.

UPWARD LEAKAGE FROM THE SHALLOW ARTESIAN AQUIFER

Highly saline water from the shallow artesian aquifer can leak upward into the water-table aquifer under certain conditions. Leakage is controlled by vertical permeability and the head differential between the water table and the potentiometric surface of the shallow artesian aquifer, which fluctuates with the tides (See Figure 26). In most parts of the island, the upward leakage is minimal because of the presence of the mud stratum that causes low vertical permeability values. Also, since the head differential is dependent on tidal fluctuations in the shallow artesian aquifer, it is not usually more than a few feet. Potential leakage is either up or down depending upon the relative position of the tide at any given time in relation to the position of the water table at the corresponding time (Figure 15). Hence, only the net amount of leakage over a sustained time period is significant.

Under natural conditions the amount of upward leakage is minimal, but when the vertical connection between the two aquifers is improved, large quantities of saline water can leak upward. Several excavations on the island were dug into or below the mud stratum and upward leakage did occur. The highly saline water that results from leakage often enters adjacent parts of both the ground-and surface-water systems.

INTRUSION FROM DEEP ARTESIAN AQUIFERS

Some of the deep artesian aquifers underlying Sanibel contain large quantities of highly saline water (See page 172). Numerous deep wells tap these aquifers. Many of these wells contain iron casing, which tends to corrode and rupture after an extended time period. Corrosion holes in the casing permit deep artesian water to leak into any of the overlying aquifers including the water-table aquifer from the well bore (Figure 26).

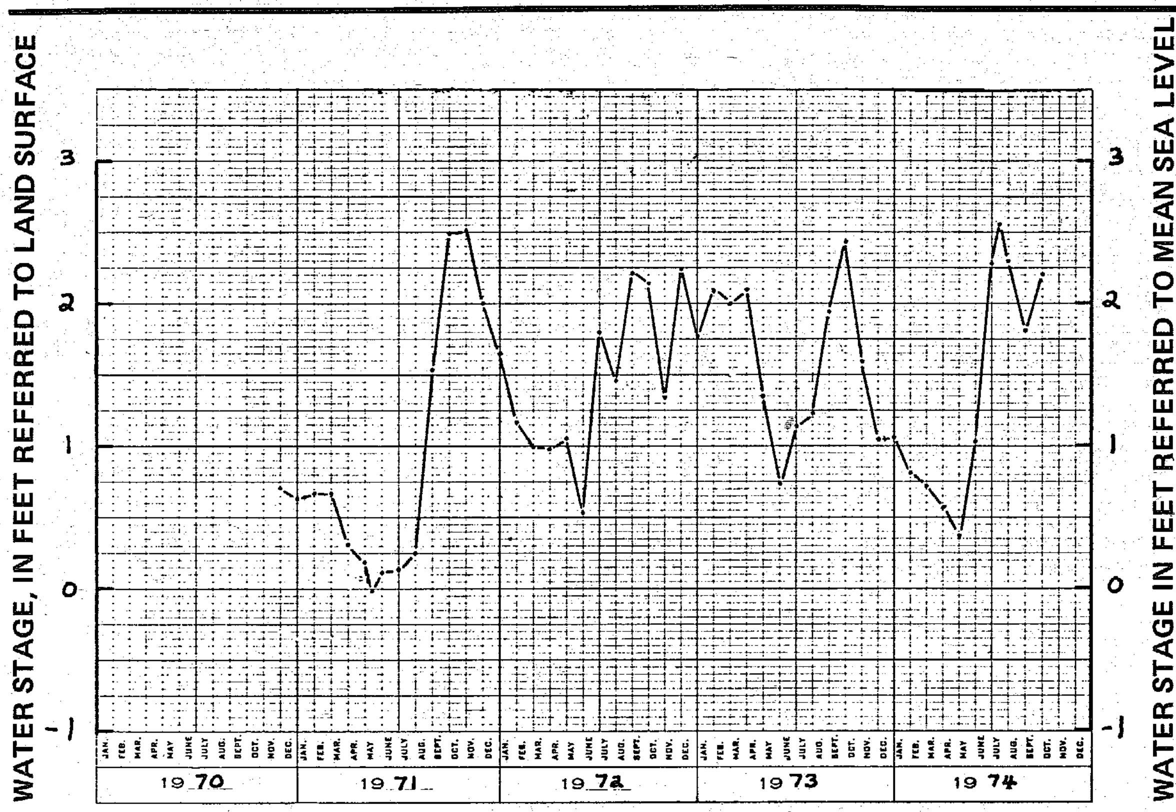

Fig. 22 - Surface water stage upstream of the Beach Road control structure, January 1971 to September, 1974.

Highly saline water from the deep artesian wells commonly enters both the surface- and shallow ground-water systems of Sanibel because of uncontrolled discharge of water out of the well at land surface. The deep wildly flowing wells tend to cause widespread contamination of freshwater areas, particularly during the dry season. Uncontrolled discharge of water from these deep wells also tends to lower the head pressure in the aquifer being tapped for the island's municipal supply.

INTRUSION RELATED TO PUMPING AND OTHER CONSTRUCTION PROCEDURE

During the excavation of lakes, ponds, and canals and during construction of buildings, certain practices were used that tended to cause intrusion of highly saline water into freshwater areas. Several shallow wells were often installed and pumped rigorously to dewater the upper part of the water-table aquifer in order to facilitate excavation. The heavy pumping in the relatively small areas tended to draw saline water from the base of the water-table aquifer and to create a stress which caused upward leakage from the shallow artesian aquifer. The pumped water, often highly saline, was sometimes discharged into freshwater areas.

The implacement of cement pilings was sometimes accomplished by jetting them into position with forcefully pumped water. Often, the water used in the process was drawn directly from the Gulf of Mexico to the construction site, which was usually located in a freshwater area. These practices are no longer permitted on Sanibel.

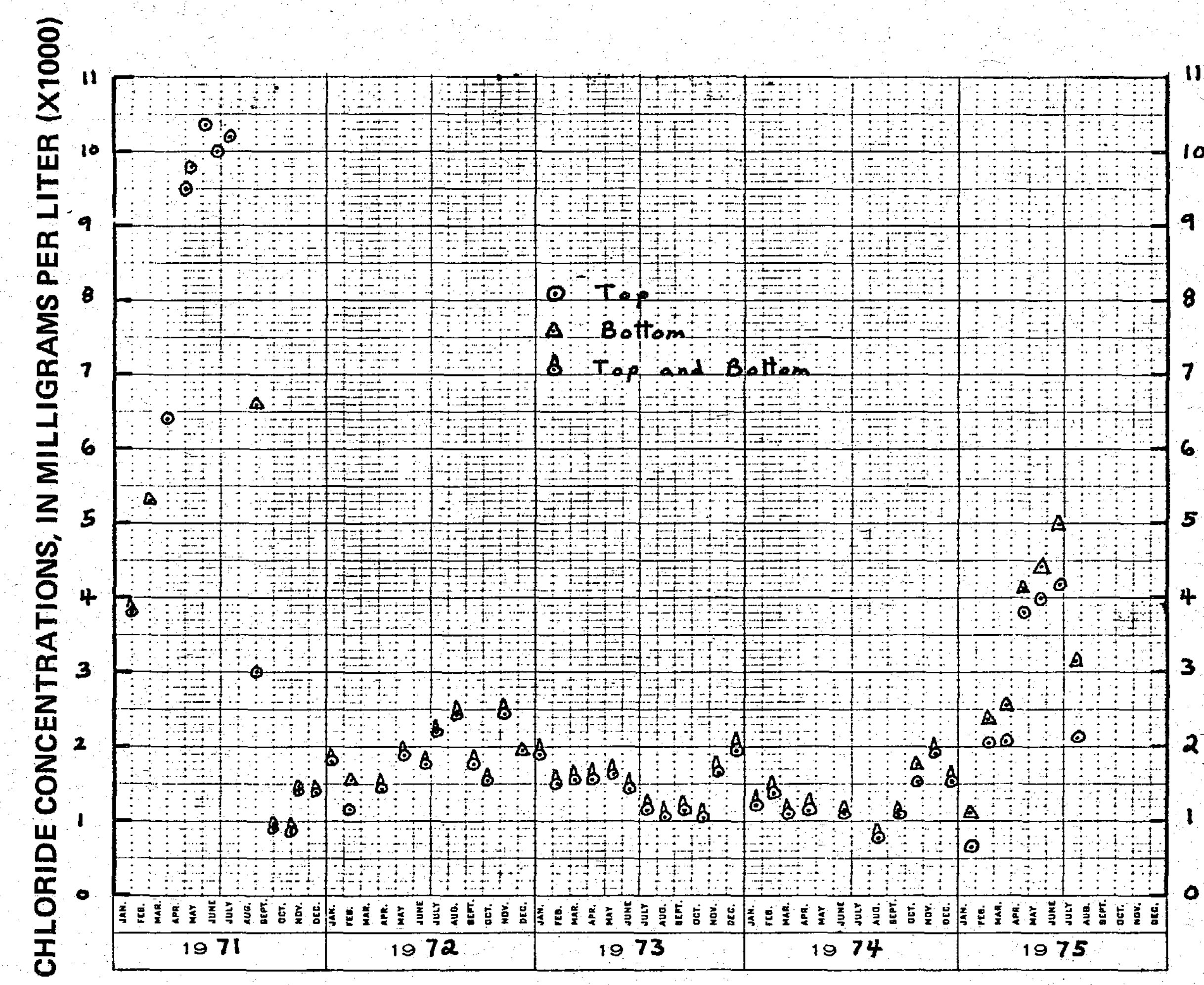

Fig. 23 - Surface and bottom chloride concentrations in the Sanibel "River" upstream of the Beach Road control structure, January, 1971 to July, 1975.

The Hydrologic Cycle

Water is, perhaps, the most unique fluid on earth. It occurs in all three forms -- gas, liquid, and solid -- on or near the earth's surface under variable natural conditions. Water is continuously being recycled from the liquid and solid state at and under the earth's surface, back to the gaseos state in the atmosphere and vice versa. The cyclic process, which includes evaporation, evapotranspiration, condensation, precipitation, infiltration, and other recharge and discharge factors, is termed the hydrologic cycle.

On Sanibel Island the quantity of water entering and leaving the surface- and ground-water systems is controlled to the greatest degree by the atmospheric processes involved in the hydrologic cycle (Figure 27). The only source of fresh water is from rainfall. All other water entering the system is saline to some degree or wastewater.

Water leaves the system in gaseous form through evaporation and evapotranspiration and in liquid form by surface water runoff and ground water discharge. A number of other factors related to man's activities also affect the changing volumes of water. The hydrologic cycle is treated quantitatively in the water budget analysis.

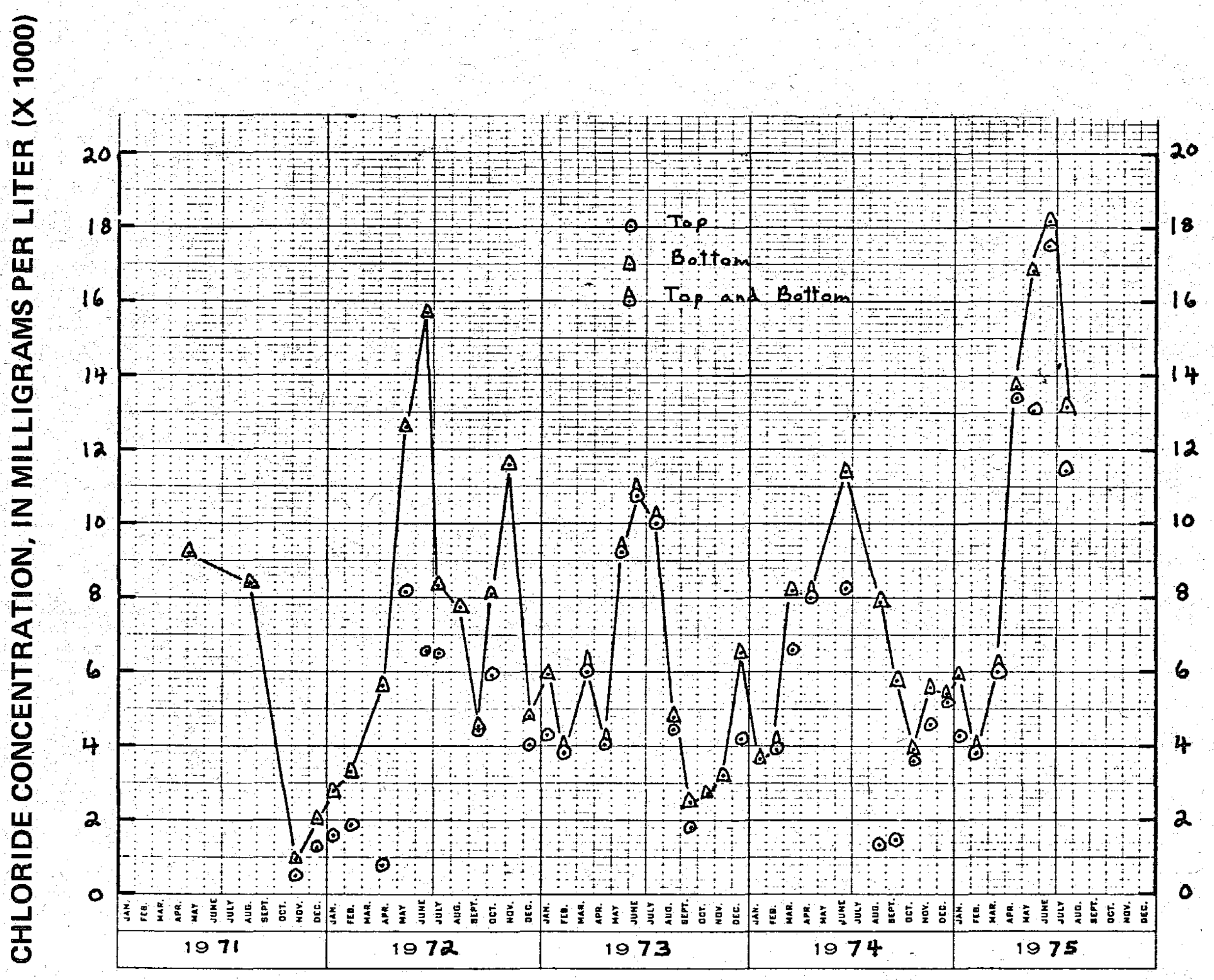

Fig. 24 - Surface and bottom chloride concentrations in the Sanibel "River" upstream of the Tarpon Bay control structure, April, 1971 to July, 1975.

Water Budget of the Interior Wetlands

A water budget is a quantitative expression of the amounts of water entering and leaving any given area through processes involved in the hydrologic cycle. The budget is calculated by carefully considering each of the inflow and outflow processes and evaluating their quantitative significance.

An annual water budget is herein calculated for the interior wetlands area of Sanibel Island. Inflow factors considered in the calculations are: precipitation, surface water inflow, groundwater inflow, upward leakage, artesian well discharge, and wastewater inflow. Outflow factors considered in the calculations are: evaporation, evapotranspiration, pumpage, surface water outflow, groundwater outflow, and in unbalanced systems, changes in groundwater storage, and changes in surface water storage.

The interior wetlands area can be considered a small basin. It consists of 3.617 acres of total area (Johnson Engineering, 1975). Of the total area, about 100 acres consist of open surface water, such as canals and lakes. The wetlands area receives about 42 inches of rainfall per year.

The water budget for the wetlands area is calculated only for the surface water system and the water-table aquifer. Only factors affecting these systems are evaluated. All volumes are calculated in acre-feet of water. One acre foot of water is equal to the volume needed to flood one acre of land surface to a depth of one foot, assuming a uniform flat surface.

Calculations of the water budget are made only for an average annual period. There is not enough

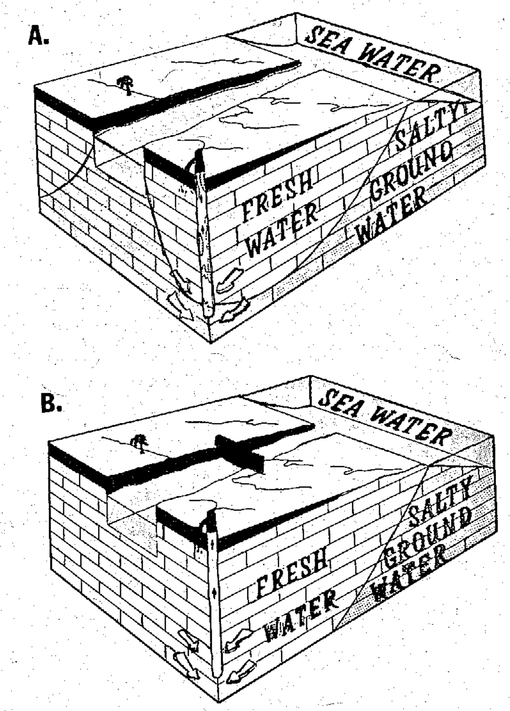

Fig. 25 - Diagram showing seawater intrusion caused by construction of an uncontrolled canal vs. a controlled canal. (from Sherwood and Grantham, 1966).

data control to give meaningful analysis to any specific year. Shorter time period calculations, such as months or weeks, are meaningless because of natural climatic variation and lack of control. The purpose of the calculations made in this report is to illustrate the present mass balance of the system

INFLOW FACTORS

The interior wetlands area of Sanibel Island is located more or less in the central part of the island with at least one beach ridge set acting as a "buffer" on all sides between the wetlands and tidal water bodies. Inflow into the system comes principally from rainfall, but the other less important factors have some effect.

Precipitation. Rainfall data has been collected by the U.S. Geological Survey at two gauge sites on the island since 1971. The three full years of record indicated that rainfall averages about 42 inches per year on the island (See page).

The quantity of inflow caused by precipitation or rainfall is calculated by multiplying the basin size in acres times the average amount of rainfall (equation 1).

$$P = A_B \cdot R_A \quad (1)$$

P = precipitation

A_B = area of basin

R_A = average annual rainfall

$$P = (42 \text{ in}/12 \text{ in/ft})(3617 \text{ acres})$$

$$P = 12660 \text{ acre-feet/year} \quad (1a)$$

Hence, the average amount of inflow due to rainfall on the wetlands is 12,600 acre-feet for an average year.

Surface Water Inflow. The only sources of surface water inflow into the interior wetlands are leakage of water through the control structures at Beach Road and Tarpon Bay Road and tidal overtopping during severe storms. Since tidal overtopping does not occur frequently, it is not considered a significant factor. The leakage at the control structures is estimated to be near one acre-foot per year. This is only a rough estimate since there is no practical means of measuring it.

Groundwater Inflow (lateral). This recharge factor involved only the lateral migration of seawater into the system because no adjacent parts of the water-table aquifer are connected to other recharge areas, other than the sea. Since the wetlands area is not directly bounded by the sea and lies several hundred feet inland on all sides, subsurface lateral migration of seawater does not directly affect it (See page 183).

There is an inward flow gradient in the water-table aquifer only during a short period of the year. Considering the magnitude of the inward gradient (less than 0.5-foot per mile), the time duration, and the transmissivity of the aquifer, groundwater inflow is near zero.

Upward Leakage of Groundwater. Water levels in the shallow artesian aquifer, which underlies the water-table aquifer, fluctuate with the tides. There is usually an upward gradient during the high part of the tidal cycle and a downward gradient during the low part. However, during most of the year, the position of the water table is lower than the potentiometric surface of the shallow artesian aquifer during the major part of each tidal cycle. The result is that a net amount of upward leakage of water occurs. The

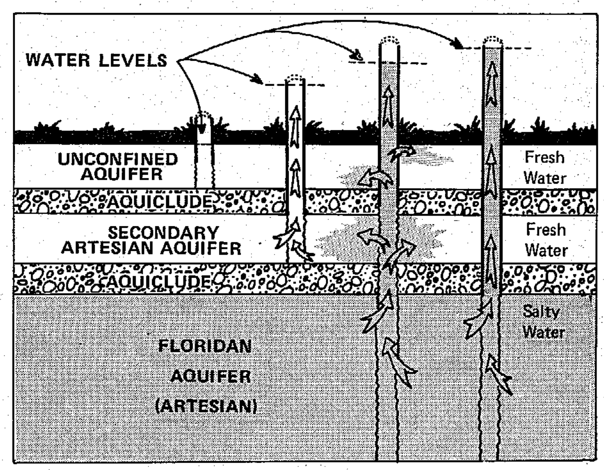

Fig. 26 - Diagram showing inter-aquifer leakage through well bores. (from Boggess, 1968).

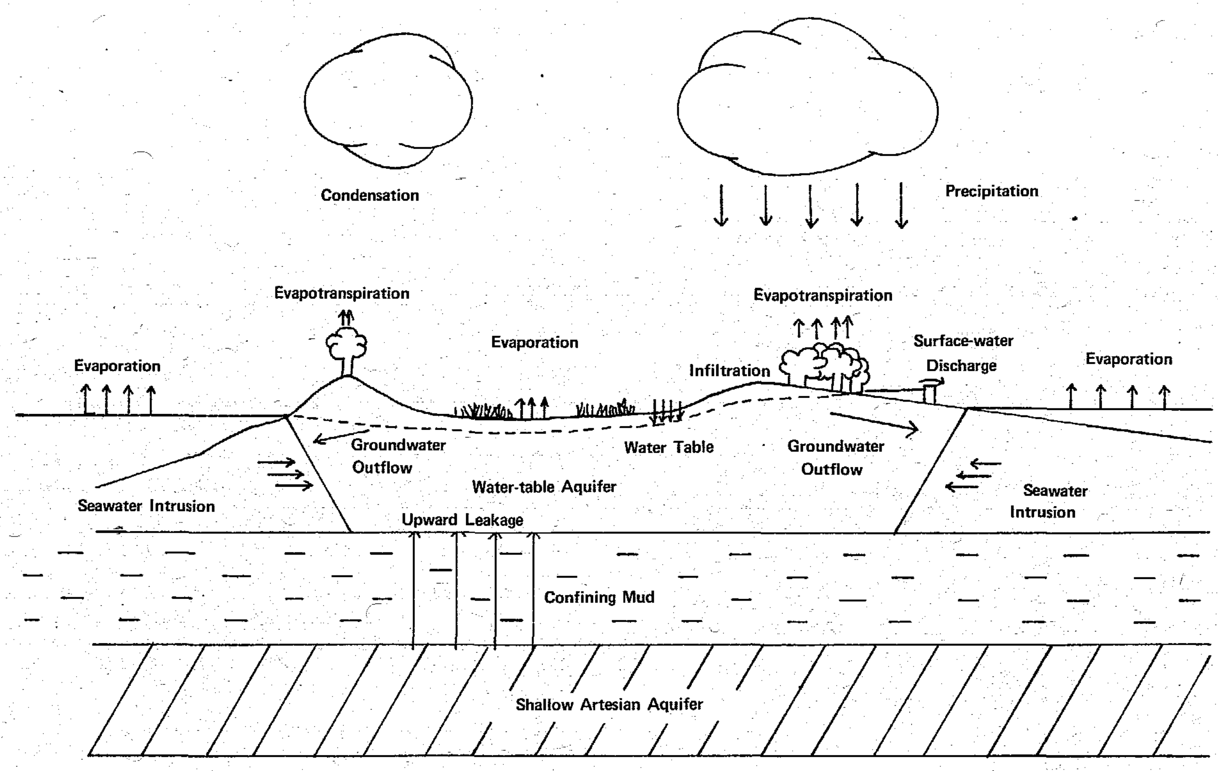

Figure 27. Diagram showing the hydrologic cycle on Sanibel Island

annual rate of upward leakage is estimated to be near 0.01 feet/year.

The total inflow contributed to the interior wetlands by upward leakage is given in equations 2 and 2a.

$$U_L = A_B \cdot C_L \qquad (2)$$

U_L = total annual upward leakage

A_B = basin area

C_L = coefficient of leakage

$$U_L = (3617 \text{ acres})(0.01 \text{ ft})$$

$$U_L = 362 \text{ acre-feet/year} \qquad (2a)$$

Artesian Well Discharge. Wildly flowing and leaking deep artesian wells contribute a significant quantity of water to the water-table aquifer. It is estimated that at least six deep wells are discharging water into the wetlands area. They are each probably flowing at an average volume of about 75 gallons per minute. Equations 3 and 3a give the contribution of artesian wells to the system.

$$D_A = N_A \cdot F_r \qquad (3)$$

D_A = total annual inflow from deep artesian wells

N_A = number of wells

F_r = average flow rate

$$D_A = (6)(121.67 \text{ acre-feet per year})$$

$$D_A = 730 \text{ acre-feet per year} \qquad (3a)$$

Wastewater Inflow. Many homes and businesses on Sanibel Island dispose of wastewater through septic tanks. Those units not utilizing septic tanks dispose of liquid waste through package or larger scale treatment facilities. A rough estimate of the daily influx of treated and untreated wastewater which enters the interior wetlands area is about 1 million gallons per day. The annual volume of wastewater entering the system is given in equations 4 and 4a.

$$W_I = \frac{V_o \times 365 \text{ days/year}}{3.26 \times 10^5 \text{ gallons/acre-foot}} \qquad (4)$$

$$W_I = \frac{(1.0 \times 10^6 \text{ gallons/day})(365 \text{ days/yr})}{3.26 \times 10^5 \text{ gallons/acre-foot}}$$

$$W_I = 1{,}120 \text{ acre-feet/year} \qquad (4a)$$

OUTFLOW FACTORS

In the absence of detailed data, it is most difficult to accurately quantify the outflow part of the hydrologic cycle. Losses occurring due to evaporation and the evapotranspiration are the most difficult to calculate. The evapotranspiration will be calculated and backchecked using better known parameters.

Evaporation. Evaporation is the conversion of water from liquid into gaseous form. A significant quantity of water is lost from the hydrologic system of Sanibel through evaporation. There are three types of evaporation losses on the island. Water evaporates from free water surfaces, from vegetated water surfaces, and from soil at differing rates.

Many factors control the evaporation loss rate from a free water surface, such as temperature, wind intensity and direction, solar radiation flux, relative humidity, heat diffusion rates, water turbidity, vapor pressure, and many others (Penman, 1948; Monteith, 1965; Wartena, 1974; Brutsaert, 1975). Since it is not possible to mathematically consider all of the atmospheric factors, the evaporation loss rate is estimated according to pan evaporation loss rates (Kohler, 1954; Brutsaert and Yeh, 1970). The estimated annual loss rate for a free water surface on Sanibel, based on pan evaporation, is 53 inches per year (Geraghty and others, 1973).

Evaporation losses are significantly increased when aquatic plants cover the free water surface. The increased loss is in some part due to transpiration losses. Regardless of which factor is dominant, the additional water loss is estimated to be at least forty percent above the free water surface loss rate (See Weert, 1974). Of the free water surface area in the interior wetlands, about 15 percent of it is affected by aquatic plant losses.

Recent experimental work in evaporation losses from sands indicates that these losses are a small percentage of the losses occurring at a free water surface (Hellwig, 1973a; 1973b; 1973c). By using the grain size data of Missimer (1973a), the water level data of the U.S. Geological Survey, and the experimental data of Hellwig (1973c), the evaporation losses from the soil is estimated to be 20 percent of the pan evaporation rate for the area of the interior wetlands. The greatest losses occur during infiltration and when the water table is near land surface. When the water table recedes to a position lower than three feet below land surface, the evaporation loss is nearly zero (See Hellwig, 1973c).

The calculated evaporation loss for the wetlands area is given in equations 5 and 5a.

$$E = (B_W \cdot E_p) + (B_V \cdot C_p \cdot E_p) + (B_L \cdot C_e \cdot E_p) \quad (5)$$

E = total annual evaporation losses

B_W = water surface area

E_p = estimated annual pan evaporation rate

B_V = vegetated water surface area

C_p = pan coefficient for excess loss from vegetated water surface

B_L = basin area (water surface area excluded)

C_e = pan coefficient for soil evaporation

$$E = (100 \text{ acres}) \left(\frac{53 \text{ in/yr}}{12 \text{ in/ft}}\right) + (15 \text{ acres})(0.40)\left(\frac{53 \text{ in/yr}}{12 \text{ in/ft}}\right) + (3517 \text{ acres})(0.20)\left(\frac{53 \text{ in/yr}}{12 \text{ in/ft}}\right)$$

$$= 3594 \text{ acre-feet/yr} \quad (5a)$$

<u>Evapotranspiration</u>. Transpiration is the process of water expulsion from plants into the atmosphere. Some water lost by plants is actually evaporated from the surface area of leaves and other parts of individual plants. Hence, the total process of water loss caused by plants is termed evapotranspiration.

In the natural system, plants act much like pumps. Water enters the plants through the roots and exits through the stem and leaves. All the climatic and environmental factors that affect rates of evaporation also affect evapotranspiration (ET). Since each different plant species has its own unique physiological characteristics, all plants have different ET loss rates. The size and density (biomass) of plants both necessitate natural areal variations in water loss rates from plants.

Little is known about the ET characteristics of the individual plant species that populate Sanibel Island. However, some qualitative assertions concerning relative water losses by certain plant communities are implied. Relatively high ET losses occur in floating aquatic plants compared to marsh and uplands species. The marsh plant community also tends to show greater ET losses than the upland plant community.

One standard approach to calculation of ET losses is to use a pan coefficient of 0.7 for the entire basin in question. The method is considered to yield a high error percentage. The calculation for ET is given in equations 6 and 6a.

$$ET = B_L \cdot C_{ET} \cdot E_p \quad (6)$$

ET = annual evapotranspiration losses

B_L = basin area (surface water excluded)

C_{ET} = pan coefficient of evapotranspiration

E_p = annual pan evaporation rate

$$ET = (3517 \text{ acres})(0.7)\left(\frac{53 \text{ in/yr}}{12 \text{ in/ft}}\right)$$

$$ET = 10{,}873 \text{ acre-feet/year} \quad (6a)$$

<u>Pumpage</u>. There are several small diameter domestic wells that tap the water-table aquifer in or near the wetlands area. However, the estimated volume pumped from these wells is so small as to have no significant effect on the water budget. The volume pumped is only a fraction of an acre-foot of water, which is generally used for irrigation.

<u>Surface Water Outflow</u>. Surface water discharge is not a common occurrence on Sanibel Island. Discharge occurs naturally only during high water conditions (See page 177). Leakage out of the system is common at the control structures. Also, some water is discharged through the Beach Road structure when it is opened by structure when it is opened by individual persons. It is estimated that discharge occurs for about 10 days at a rate of 10 cubic feet per second in an average year. The volume also includes leakage. The total volume is given in equations 7 and 7a.

$$S_o = D \cdot t \quad (7)$$

S_o = annual surface water discharge

D = average rate of discharge

t = time duration of discharge

$$S_o = \frac{(10 \text{ ft}^3/\text{sec})(60 \text{ sec/min})(60 \text{ min/hr})(24 \text{hrs/day})(10 \text{ days})}{43{,}560 \text{ ft}^3/\text{acre-ft}}$$

$$S_o = 20 \text{ acre-feet/yr.} \quad (7a)$$

Groundwater Outflow. An outward gradient toward major tidal water bodies in the water table aquifer only occurs during the wet season (Gulf of Mexico and Pine Island Sound). The wet season gradient is usually less than two feet per mile and, hence, little ground water is discharged into the Gulf and Pine Island Sound.

Where the water-table aquifer borders tidal canals, a significant quantity of water is lost from the system. A rather large amount of water leaks from the ground water system at and around the Beach Road control structure. The total quantity of water leaked to tidal canals is estimated to be about 100 acre-feet/year.

A large quantity of groundwater flows laterally into the surface water system of the interior wetlands where much of the water is lost to evaporation. Hence, this water loss has already been calculated.

MASS BALANCE OF THE ANNUAL WATER BUDGET

The quantity of water entering and leaving the hydrologic system of Sanibel varies from year to year. However, the position of the water table and the surface water stage both reach similar highs and lows from year to year. There are no progressive water level trends occurring in the shallow groundwater system of Sanibel at present.

Since this analysis deals with an average year in a system where similar quantities of water are held in storage from year to year, inflow into the system must be equal to outflow from the system in an average year. This concept of accounting for all volumes of water entering and leaving the system is termed mass balance. It is analogous to conservation of mass and energy in physics. Water is neither created nor destroyed in the hydrologic system, but it only changes form.

In an unbalanced system, where a progressive decline in water levels is observed through several years, a correction must be added to the equation in order to achieve mass balance. The correction factor is the change in storage.

In the wetlands of Sanibel, the system generally shows no change in storage from year to year. Hence, no storage factor is needed to balance the budget equation. Within a given year, the volume of water in storage varies considerably. The water budget or mass balance equation is given in equation 8. The volumetric analysis of the mass balance is given in Table 2.

$$P + S_I + G_I + U_L + D_A + W_I \quad (8)$$

$$= \Delta S + ET + P_u + S_o + G_o$$

P = average annual precipitation

S_I = annual surface water inflow

G_I = annual groundwater inflow

U_L = annual upward leakage

D_A = annual artesian well discharge

W_I = annual waste water inflow

ΔS = change in total storage

E = annual evaporation

ET = annual evapotranspiration

P_u = annual pumpage

S_o = annual surface water outflow

G_O = annual groundwater outflow

Note that the inflow total does not equal the outflow total in Table 2. This is caused by errors in the process of evaluating each factor involved. The entire analysis is rather subjective and should be considered semi-quantitative. More data and a refined mathematical treatment would be needed to improve the analysis.

Table 2. Mass balance of the hydrologic budget for the interior wetlands of Sanibel Island.

Inflow Factors[1]		Outflow Factors[1]	
P =	12,660	S =	0
S_I =	1	E =	3,594
G_I =	0	ET =	10,873
U_L =	362	P_u =	0
D_A =	730	S_o =	20
W_I =	1,120	G_o =	100
	14,873	TOTAL	14,587

[1]All values are in acre-feet/yr.

ANNUAL WATER STORAGE IN THE INTERIOR WETLANDS

During the year a certain amount of water is held in temporary storage in both the water-table aquifer and the surface water system on the island. The maximum quantity of water in storage during the wet season is much greater than the minimum quantity in storage during the dry season. The net charge in storage from the maximum part of the water lost from the system through E, ET, and other factors. Herein, the storage loss of the surface water system and water-table aquifer is treated as a whole. Equations 9 and 9a give the total maximum quantity of water in storage in the wetlands area, while equations 10 and 10a give the minimum quantity. Equations 11 and 11a yield the total annual charge in storage.

$$S_{max} = (B_L \cdot A_T \cdot C_s) + (B_w \cdot W_T) + (B_w \cdot (A_T - W_T) \cdot C_s) \quad (9)$$

S_{max} = maximum quantity of water in storage (both surface- and groundwater systems)

B_L = basin area excluding surface water area

A_T = maximum saturated thickness of the water-table aquifer

C_s = storage coefficient of the water-table aquifer

B_w = area of surface water

W_T = average maximum thickness of surface water

$$S_{max} = (3517 \text{ acres})(17 \text{ ft})(0.23) + (100 \text{ acres})(5 \text{ ft}) + (100 \text{ acres})(17 \text{ ft} - 5 \text{ ft})(0.23)$$

$$= 14{,}527 \text{ acre-feet} \quad (9a)$$

$$S_{min} = (B_L \cdot A_s \cdot C_s) + (B_w \cdot W_s) + (B_w \cdot (A_s - W_s) \cdot C_s) \quad (10)$$

S_{min} = minimum quantity of water in storage (both surface- and ground-water systems)

A_s = minimum saturated thickness of the water-table aquifer

W_s = minimum thickness of surface water

$$S_{min} = (3517 \text{ acres})(13 \text{ ft})(0.23) + (100 \text{ acres})(3 \text{ ft}) + (100 \text{ acres})(13 \text{ ft} - 3 \text{ ft})(0.23) = 11{,}069 \text{ acre-feet} \quad (10a)$$

$$\Delta S = S_{max} - S_{min} \quad (11)$$

$$\Delta S = (14{,}527 \text{ acre ft}) - 11{,}069 \text{ acre ft}) = 3{,}458 \text{ acre feet} \quad (11a)$$

The volume of water calculated as the total ΔS is considered by the author as a close approximation of the maximum volume of real freshwater in the system. It should be noted that at the dry season minimum there is probably little or no freshwater by definition (water having less than 1000 mg/l dissolved solids). Also, the 4-foot range in water-table fluctuation is a minimum value, which makes the 3,458 acre-feet the greater annual change in storage.

Conclusions

The following conclusions are made with regard to maintaining the beneficial natural qualities of the hydrologic system on Sanibel Island or improving it.

(1) The channelized surface water system of Sanibel Island is in poor environmental condition. Highly saline water enters the system through leaky control structures at Beach Road and Tarpon Bay. Dissolved oxygen is low and highly saline water is trapped in bottom depressions.

(2) It appears necessary to prohibit excavation-construction of tidal canals.

(3) Any interior excavations to be dug on Sanibel, such as channels, canals and real estate lakes, should be discouraged and designed according to exacting standards which will guarantee maintenance of acceptable water quality. The depth of such excavations should in no case be greater than 5 feet below mean sea level. The banks should be gently sloped. The excavations should be sloped and oriented to allow maximum oxygenation by prevailing winds. It is also suggested that to restore past damage dissolved oxygen enhancement and/or artificial circulation devices be installed in existing degraded water bodies such as wind-driven air pumps or wind-driven paddle wheels.

(4) Liquid waste should not be permitted to enter the surface water system. It is clear from the evidence that the use of septic tanks on Sanibel be discontinued.

(5) The Sanibel "River" system could be greatly improved by upgrading the control structures at Beach Road and Tarpon Bay. New structures of the "flapper-type" set to maintain a minimum surface water stage of 2.5 feet at the outflow points would appear advisable. It is clear that the channels should be cleared of organic detritus and the new channel designed to allow maximum oxygenation of the water. A new channel with established uniform gradient and of depth enough to discourage growth of cattails is needed. Large box culverts are needed at points where roads cross the channel. The designing of the system should incorporate the potential for maintaining the water levels at 3.0 to 3.5 feet or higher in the interior wetlands if this should prove feasible (See Recommendation No. 5).

(6) A permitting system should be developed regulating all newly proposed deep artesian wells and permissible water use criteria should be developed. All "wildly flowing" wells or any deep artesian wells that are damaged or improperly constructed should be plugged completely as soon as possible.

Recommendations

The following recommendations are aimed at specific additional actions needed to insure the soundest program of natural resource management.

(1) Cooperative programs between the U.S. Geological Survey and the City of Sanibel should be maintained and strengthened in order to continue the collection of relevant hydrologic data.

(2) A detailed investigation of the deep artesian aquifers underlying the island should be made. It should include test holes, a multi-well pump test to determine aquifer properties, detailed water quality analyses, and the establishment of several deep observation wells. The pump test should be made as soon as possible.

(3) All deep artesian wells should be located and investigated.

(4) A feasibility study should be made of disposal of liquid waste by deep-well injection or by land-spreading in uninhabited areas.

(5) A study of water impoundment should be made to find out the feasibility of maintaining a 3.0 or 3.5-foot water stage in the interior wetlands. This study should include the making of a one-foot interval contour map of the island to aid in drainage analysis.

Summary

Sanibel Island is underlain by at least three major aquifers: the unconfined, water-table aquifer, the shallow artesian aquifer, and the lower Hawthorn-Suwannee Aquifer. All of the aquifers are separated by confining clays or muds which tend to inhibit natural vertical water movement.

Municipal water supply for the City of Sanibel is taken from wells tapping the lower Hawthorn aquifer. There is considerable variation in water quality within this aquifer and its capacity to yield sustained quantities of adequate quality water is unknown.

The shallow artesian aquifer underlies the island at depths ranging from 20 to 30 feet below mean sea level. Water levels in the aquifer fluctuate with the tides. This aquifer generally contains highly saline water. Because of the tidal fluctuation, the poor quality water in the shallow artesian aquifer can leak upward into the water-table aquifer and cause degradation of water quality. In the natural system, the quantity of leakage is relatively small, but man's activities, such as excavation of deep lakes and canals, can cause greater leakage rates.

Fluctuations of the water table reflect changes in storage within the aquifer. Climatic factors and the activities of man control water level changes within the aquifer.

Fresh water occupies the upper part of the water-table aquifer. The position of the fresh water in the hydrologic system is precarious. The freshwater zone can easily be intruded by saline water in a number of natural ways and can be caused by man's activities.

The channelized surface water system of Sanibel Island is in poor environmental condition. Highly saline water enters the system through leaky control structures at Beach Road and Tarpon Bay. Dissolved oxygen is low and highly saline water is trapped in bottom depressions.

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Mr. Richard Workman of the Sanibel-Captiva Conservation Foundation is greatly acknowledged for his effort in collecting hydrologic data and his leadership in developing water resource management programs.

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APPENDIX 2

APPENDIX 2

VEGETATION

by Durbin C. Tabb, Eric J. Heald, Gary L. Beardsley, Martin A. Roessler, and Taylor R. Alexander

Tropical BioIndustries Development Company was commissioned by The Conservation Foundation to conduct a reconnaissance survey of the upland vegetative communities, the interior wetland complex, and the mangrove communities of Sanibel Island. In this, the professional staff of Tropical BioIndustries constituted part of a larger task force assembled by The Conservation Foundation to produce baseline documentation of the natural resources of the island. The completed document, describing the vegetative system, also includes information of geology, hydrology, marine environments, mammals, birds, and reptiles, and is offered as an information source around which a realistic land-use plan for Sanibel can be formulated. The task force placed primary emphasis on wetland systems since these are often severely threatened and easily disrupted natural communities.

The roles of wetlands, both freshwater and saline, are varied, and their significance is becoming increasingly well-documented under careful investigation. Their more important roles include production of materials basic to many natural food chains, specialized habitats for aquatic species of economic importance, buffer zones for flood protection, freshwater recharge, and filtering and cleansing of water emanating from adjacent upland areas. It should be noted, however, that the above roles are not common to all wetland systems and are not performed with equal efficiency; hence, generalizations can be misleading.

The existence and efficient functioning of most wetland systems results from the subtle interplay of natural parameters; for instance, water flow patterns, duration of inundation, dissolved nutrient levels, soil type, and depth. Most of these parameters can be easily disrupted or altered by ill-planned human activities, causing significant, frequently deleterious, and often irreversible changes in the total role or "value" of the wetland community.

The information and recommendations presented in this report are a distillation of the collective experience of its authors in South Florida environments, including Sanibel Island, and of field observations made on site in June 1975. Two field trips, each of 3 days duration, were made by a 4-man team from Tropical BioIndustries and by Dr. Taylor Alexander, Botany Department, University of Miami.

The program consisted of assembling available literature concerning Sanibel, followed by field verification to produce a base vegetation map and community descriptions. Recommendations offered for consideration in this report were developed as a result of discussion among ourselves and with John Clark, Conservation Foundation, following analysis of the field observations.

We are indebted to Mr. Richard Workman of the Sanibel-Captiva Conservation Foundation for his invaluable assistance during field trips

and for local knowledge freely imparted for our benefit. John Clark, as coordinator of the task force, is to be complimented on a clear delineation of the objectives of the study. The authors donated the time required for report writing, map production and interim conferences following the systems survey, since the production of this resource evaluation for use in land planning is believed to be clearly in the public interest.

Mangrove Communities

Increased attention and scientific investigation over the past 10 to 15 years has produced adequate documentation of the importance of specific community associations in the maintenance of highly productive estuarine ecosystems. These high levels of productivity are manifested in obviously tangible values such as commercial and sports fisheries, as well as in abundant bird populations. It has also become apparent that all mangrove communities do not perform identical roles or contribute in similar fashion to estuarine food chains. Consequently, it seemed desirable, in preparing assessments of the resource base of Sanibel Island, to classify and assess as fully as possible the role and importance of the island's mangrove communities, rather than merely describing their geographic location.

THE ECOLOGICAL ROLE OF MANGROVES

Among the roles attributed to mangrove communities by various workers are: land building and stabilization, filtering of suspended material, assimilation of dissolved nutrients, storm wave attenuation, aquatic and terrestrial wildlife habitat, and contribution to estuarine food chains. The latter three roles are probably of much greater overall significance than the former three.

General Function: As primary colonizers of emergent oyster bars, red mangroves frequently create islets which gradually grow in size by a process of accretion of silts around the numerous prop-roots. Similarly, in quiet backwater areas, the prop-roots of red mangroves and the pneumatophores of black mangroves trap sediments and gradually elevate or extend land surfaces. The process is well documented.[1,2] In the 40 or 50 years since photography was first available, several instances of the closure, partial filling, or subdivision of bay systems by mangroves has been recorded.

The ability of reds and blacks to trap debris has led to speculation on their importance as physical filters; removing suspended materials from the water column. This they undoubtedly do, but the biological significance of such removal is obscure. South Florida bay systems vary seasonally and from year to year between extreme clarity and extreme turbidity. No correlation between either condition and overall productivity or changes in community structure and water clarity has yet been demonstrated.

It has been postulated that mangrove communities remove dissolved primary nutrients (principally inorganic ions) from waters flowing through them from upland sources. Indications are that coastal mangrove communities are dependent to some extent on nutrients emanating from upland areas.[3] On the other hand, the State's best developed mangrove forests lie at the seaward end of the vast sawgrass regions of Everglades National Park, where dissolved nutrients are in extremely low concentrations after the fresh water has passed slowly through the sawgrass. It has also been suggested that certain mangrove communities (particularly black mangroves) contribute to estuarine productivity by providing a source of dissolved primary nutrients in organic form.[3] Thus, the picture is unclear, and the processes involved are not well understood.

The importance of mangroves as buffers against hurricane-generated storm waves is indisputable. The prop-roots of reds and pneumatophores of blacks, as well as the often densely situated trunks, form an effective impediment to the forward progression of wind-driven tidal surges.[2]

Food Chain Support: The most significant biological roles played by mangrove communities, in our opinion, are those as wildlife habitats and as contributors to estuarine food chains. It is primarily these factors which have led to increased investigation and public demands for adequate protection of mangrove systems.

The undoubted importance of the mangrove-dominated estuaries of South Florida has often been emphasized. Several commercially valuable marine species, such as pink shrimp, mullet, gray snapper, red drum and blue crab, which use the estuaries as a nursery and feeding ground, has been listed.[4] It has been shown that at least one species of economic and recreational value, the spotted seatrout, appears to be dependent on the estuary during the greater part of its life cycle.[5] A measure of the potential of such nursery areas is the volume of the commercial shrimp catch from the Dry Tortugas grounds, which in 1973 exceeded 16 million pounds, with revenue of over $14 million paid to fishermen.

Red Mangroves: Tidal and riverine red mangrove forests in South Florida produce annually over eight metric tons dry weight per hectare of leaf and twig debris, the majority of this being leaf material.[6] In tidal and riverine situations most leaf breakdown occurs under submerged or, at least, damp conditions. In these situations fallen red mangrove leaves are quickly subjected to the grazing or browsing activities of several species of invertebrates.

The most important means of energy transfer (i.e., utilization of plant material by animals) in a detrital system depends upon the ability of bacteria and fungi to break down and assimilate resistant plant substances such as celluloses and lignins. Soon after a red mangrove leaf falls from the tree its tissues are invaded by several species of fungi and bacteria. The complex sequence of microbial succession has been detailed by Fell and Master.[7]

The net result of this microbial invasion is a relative increase in the potential food value (as measured by protein content) of any specific particle of disintegrating leaf. When such a particle, relatively rich in protein of microbial origin, is ingested by a detritus feeder the only components of the particle which are in an easily digestible form are the bacteria and fungi, along with nematodes and protozoa which may be feeding upon them.

In South Florida this important trophic level of detritus feeders (primary consumers) appears to include roughly 12 species of crustaceans (4 amphipods, 4 mysids, 2 carideans, 1 penaeid and a xanthid crab), 6 fishes, 2 polychaetes, several copepod and isopod species, and larval chironomids.

Although many individual food chains are involved, the principal flow of energy follows the pathway: mangrove debris and detritus → bacteria and fungi → primary consumers (detritus consumers) → secondary consumers (lower, middle, and top carnivores).

The secondary consumers, which include virtually all the important sport fish and most commercially important species, are basically carnivorous, and depend, directly or indirectly, on the omnivorous or herbivorous primary consumers and converters we have just discussed. Details of the food habits of most of the organisms involved are given by Odum and Heald.[8]

We have referred to primary consumers such as small fish and crustaceans as removers and exporters of detritus from red mangrove systems. This cycle can only operate efficiently if the consumers have ready access to the detritus source. A system of narrow creeks and shallow ponds, coupled with strong tidal action, is necessary for effective penetration of the marsh by these organisms.

<u>Black Mangroves and Mixed Species Forests</u>: Black mangrove-dominated plant communities form in many areas a continuum of tree cover stretching from the approximate mean high tide line, or somewhat below it, to higher areas affected only by storm tides. The ecological roles of these communities are obviously varied and different parts of the forest almost certainly contribute to estuarine food chains in different ways. There are three major types of communities as described below.

1. "Tidal" black mangrove communities. These are forests in which the visual dominant is the black mangrove, but in which considerable numbers of reds may exist, often as an understory to the larger blacks. In places the understory reds may account for almost 40 percent of individuals, and perhaps 25 percent of the total above-ground tree biomass.

These forests are found under several situations. Commonly, they occupy a slightly elevated natural levee behind the shoreline red mangrove stands of large islands and along many water courses. They also frequently form the center portions of small islands. Extensive tracts also occur in areas where the shoreline levee is absent or indiscernible. In these situations major portions of the forest are more distant from open tidewater or creeks and the proportion of red mangroves, though still significant, is somewhat reduced.

The tidal black mangrove communities are, for the most part, in frequent contact with tidal waters. In many places they may be close to the level of mean high tide and are strongly flushed by the higher tides of the year which transport from the forest a considerable percentage of the accumulated debris and detrital products. These "tidal" communities, particularly in their seaward portions, probably perform roles similar to those of tidal red mangroves.

2. "High" black mangroves. These "non-tidal" systems range from clearly supratidal to spring tide elevations. The majority of these communities, thus, are flooded only by seasonal rains and extreme seasonal tides. Consequently, the forest floor is irregularly submerged and emergent, but is rarely completely dry. Black mangroves are overwhelmingly dominant, although white mangroves can be locally very common. Salt-tolerant plants such as glasswort and saltwort often form a sparse to dense ground cover. Most of the leaf litter produced by these forests probably decays <u>in situ</u>, since flushing by rainwater runoff or seasonal tides is infrequent and weak. Much of the breakdown product is thus recycled within the community, or forms peat. An unknown proportion is transported out of the high black forest by tides and runoff.

An important biological function of the high black mangrove systems is their apparent role in the mosquito linked food chain. The wet-dry fluctuations experienced by the higher portions of the black mangrove forest are a prerequisite for the successful propagation of salt marsh mosquitoes.[9] These breed in enormous numbers when shallow flooding occurs over eggs deposited earlier on exposed ground. The resultant aquatic larvae, which feed on particulate organic detritus, provide seasonally abundant food source for a select group of fishes, notably <u>Gambusia affinis</u> and <u>Fundulus confluentus</u>, which are adapted to exploit the shallow and ephemeral waters of the high black mangrove zone and adjacent grass marshes.

As these waters gradually dry up, the fish populations, having meanwhile produced several broods of young, move back into more permanent waters in the "tidal" black mangrove and red mangrove zones, or become concentrated in disappearing upland fresh and brackish ponds. Wading birds congregate at the receding ponds and exploit the concentrations of easily available prey. An indication of the magnitude of this food source is provided by Kahl's estimates[10,11] that a breeding colony of wood stork (<u>Mycteria americana</u>) consisting of 6,000 pairs and their young require 1.2 million kilograms (2-1/2 million pounds) of small fishes during a 60-65 day nesting period.

By such pathways, the high mangrove communities apparently contribute to the support of adjacent estuarine waters, provided that their function is not impeded by larvicide spraying, ditching or impounding.

3. "Impounded" forests. These forests are characteristically occupied by a mixed black and red mangrove community, although in some places white mangroves predominate, and in others an almost monospecific stand of blacks occurs. These forests are found in situations where natural levees, perhaps old beach ridges or storm drift lines, are sufficiently complete to cause impoundment of spring tide waters and local rainfall for considerable periods of the year. During drought periods evaporation from such impoundments leads to hypersaline conditions and can cause defoliation and death of trees.

Breakdown of forest litter occurs largely within the impounded area, producing copious deposits of flocculent organic particles so richly colonized with sulfur bacteria that they often assume a purple cast. Fresh water or tidal flow is evidently inadequate to transport this floc or "liver mud" from the system during "average" years, with the result that the floc layer attains depths in excess of two feet in places. Such organic masses, if disturbed or flushed from the impoundments by hurricanes, may cause massive oxygen depletions in adjacent estuarine waters.[12]
Liver mud was found up to 5 inches in thickness within the natural impoundment on Sanibel Island. We suspect that drying of the impoundment during the winter allows oxidation of the floc, and hence prevents buildup to greater depths.

THE SANIBEL SURVEY

Delineation and evaluation of mangrove communities was accomplished by extensive ground observation in conjunction with aerial photography at a variety of scales. The base photography used during field investigations was the 1974 series of black and white verticals produced by Lee County at a scale of 1"=300' for tax purposes. Additional black and white photography at scales of 1"=1000' and 1"=2000' (U.S. Dept. of Agriculture, Soil and Conservation Service, 1944 and 1970 series) was also used for reference purposes. Photo-interpretation was also greatly aided by a series of oblique, false-color, infra-red aerial photographs taken by Mr. W. Byle of Environmental Services Unlimited and provided by The Conservation Foundation.

Field observations, providing "ground truth" for the apparent registers on aerial photography, were performed by means of multiple transects and by numerous spot checks of photographic features. In the course of field observations we determined, as fully as possible, species dominance, vegetative form, geographic extent of specific associations, and tidal relationships. The overall classification or characterization of specific communities was determined by combinations of features which we and other workers have found to be reasonably reliable indicators in other areas of South Florida. Among these are species mix, salinity, amount and character of leaf litter, pneumatophore height, periphyton communities, substrate characteristics, and the presence or absence of certain fish and invertebrates.

With the time and resources available it was possible only to classify the major mangrove communities and to assess their respective roles and importance in the light of previous experience of similar community "types" in other South Florida locations.

We also attempted a preliminary determination of possible interrelationships between the coastal mangrove communities and freshwater runoff from adjacent uplands, since, in the event of a close relationship, future human activities in upland areas could affect the functioning of mangrove communities.

The Setting: It has been estimated[13] that 5,120 acres of mangroves formerly existed on Sanibel. We estimate that 2,800 acres exist today and we believe that the earlier figure of 5,120 acres to have been in error. The major portion of these (2300 acres) are included in the J.N. "Ding" Darling Wildlife Refuge. Additional mangroves exist north of Wulfert Road, near Wulfert Pass on Runyon Key, Albright Island, Silver Key, fringing Dinken Bayou, Clam Bayou, Old Blind Pass, and Blind Pass. Of these, the mangrove and beach ridge community on Bowman's Beach is protected as a park or wildlife refuge.

Two ancient beach ridges are apparent in the mangrove forest association (Figure 1). Running roughly east-to-west they divide the system into an outer, middle, and inner system with tidal effect and amplitude diminishing in a landward direction. Tidal flushing is strongest in the outer system, practically non-existent in the western pockets of B and C, and moderate to strong only in the vicinity of scour channels of the eastern halves of B and C.

The excursion distance of a particle will be long in sector A but extremely short in C. In fact, organic production in the western ends of B and C appears greater than the ability of mixing and flushing to assimilate by oxidation, or remove the material to the adjacent bay. For this reason, heavy organic buildup occurs in those shallows with a resultant high BOD, methane production, and a dominance of blue-green algae in the system. The construction of the scenic roadway across these already poorly flushed systems can only aggrevate the problems and, in fact, we observed severe hypersalinity (i.e., salinity in excess of 50‰) in early June, and mangroves within the confines of this system of roads appear to be stressed.

As a result of low oxygen, variable salinity, and a stressed flora, the fauna is also stressed. Only a few species of fish and invertebrates, which are euryhaline and adapted morphologically or physiologically to withstand low oxygen conditions, can occur in areas B and C. Thus, species diversity is low, but the few successful species can exist in large numbers.

COMMUNITY DESCRIPTIONS

For convenience of description we have recognized six categories of mangrove communities. They are principally, though not exclusively, geographical in character. They are as follows:

(1) communities east of Wulfert Road, between Wulfert Channel in the north and Kesson Bayou in the south;

(2) forests within the Refuge stretching from Kesson Bayou east to the western shore of Tarpon Bay that lie external to the "Darling Memorial Drive" levee;

(3) areas contained within the confines of the "Darling Memorial Drive" levee;

(4) eastern shores of Tarpon Bay to Dixie Beach Boulevard;

(5) communities east of Dixie Beach Boulevard;

(6) miscellaneous islands and pockets on the southern aspects of the island.

Within each of these geographic areas, one to several biologically distinct communities exists. The approximate bounds of these are indicated on the vegetation map (See Figure 1) at a scale of 1"=1000'.

(1) East of Wulfert Road: From the shore of Wulfert Channel-Blind Pass, for a distance of approximately one-third mile south, the mangrove forest is remarkably uniform in character. It commences seaward of an abrupt and well-defined scarp at the margin of high elevation lands on which sea grape, saw palmetto, cabbage palm, yucca, wax myrtle, and saltbush are dominants.

The mangrove forest is composed of approximately 60 percent reds to 30 feet in height; 40 percent blacks to 40 feet and occasional white mangroves up to 40 feet. Size range of trees is relatively narrow, the canopy is virtually closed at 25 feet, very little discrete clumping of species is evident, and tidal influence is moderate to strong. We observed no well-defined tidal swales or creeks; tidal inundation appears to be in the form of a uniform sheet flow.

South of this community, where the shoreline curves eastward away from Wulfert Road, a much more varied set of communities occurs as far south as Holloway Bayou. A typical "composite" transect from the abrupt edge of the upland "escarpment" to Pine Island Sound would be as follows.

The most landward community consists of a narrow band of red mangroves 25 to 30 feet high located in a shallow swale which is virtually continuous from north to south along the edge of the upland. Standing water, from higher than average tides and from local rainfall, is a frequent feature. Tidal flushing, however, is weak and a considerable leaf litter layer is accumulating.

Seaward of this line lies a slightly wider band dominated by an open forest of 25' black mangroves with a sparse understory of reds. This zone is somewhat more strongly influenced by tides, although a litter buildup is evident. Such buildup is relatively uncommon in tidal forests strongly dominated by black mangroves because gastropods, such as Melampus coffues, usually consume fallen leaf material sufficiently rapidly to prevent accumulation.

The weak to moderate tidal nature of the above communities is explained by a slightly elevated berm which lies seaward. This is characterized by a dense forest of somewhat spindly reds to 20 feet in height, with a few scattered blacks of similar height. The latter are probably much older than the former.

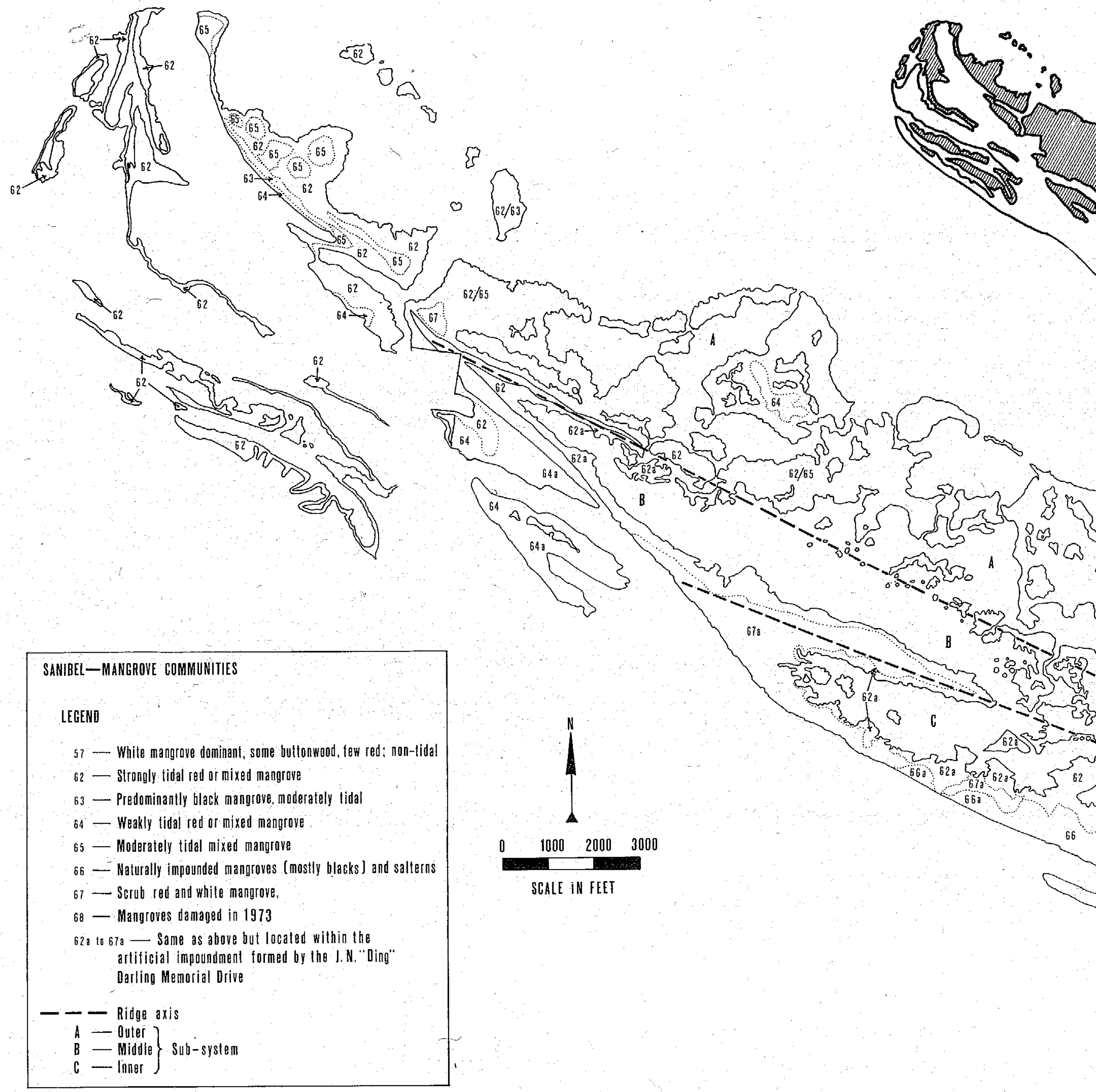
Between this point and the open shoreline of Pine Island Sound, the forest becomes variously dissected by deeply penetrating tidal channels and swales meandering around the fringes of discreet blocks of forest, many of which are, in effect, shallow basins with slightly raised rims.

The low-lying channels with wide tidal swales are mostly colonized by red mangroves, some of which are 50 feet high. The canopy is dense and is virtually closed at 25 feet. Black mangroves tend to occur in patches, where they may constitute up to 30 percent of the individual total. These areas, and the shallow basins which they drain, are frequently inundated and are well flushed by normal tides. The basins are characterized by a mixture of red and white mangroves to 50 feet in height, forming a relatively open canopy beneath which Batis occurs in sparse clumps.

Just north of Holloway Bayou a tongue of high land projects southeast toward Kesson Bayou and the mangrove communities to the south, east and west, on both sides of the bayous, again become more uniform. They are strongly influenced by tidal action, except in the extreme east close to the upland, and consist of a mix of red and black mangroves to 30' in height. Reds tend to predominate increasingly as one approaches the open bayous, but blacks are still frequently encountered.

(2) Kesson Bayou to Tarpon Bay: This tract contains the major portion of the most ecologically significant mangroves on the island. As can be seen from the vegetation map, the dominant communities are tidal red or mixed red and black mangroves. The overwhelming feature is the complex system of red mangrove islets and interconnecting bays from Hardworking Bayou to Tarpon Bay.

Very little time was spent in examining these island systems since they appeared to be very similar in nature to the familiar islands of Whitewater Bay and Florida Bay, and to the systems in Fahkahatchee Bay studied by Carter et al.[14] Their important role as exporters of detrital material, and as shallow water and edge habitats, is well documented.


SANIBEL—MANGROVE COMMUNITIES
LEGEND
57 — White mangrove dominant, some buttonwood, few red; non-tidal
62 — Strongly tidal red or mixed mangrove
63 — Predominantly black mangrove, moderately tidal
64 — Weakly tidal red or mixed mangrove
65 — Moderately tidal mixed mangrove
66 — Naturally impounded mangroves (mostly blacks) and salterns
67 — Scrub red and white mangrove,
68 — Mangroves damaged in 1973
62a to 67a — Same as above but located within the artificial impoundment formed by the J. N. "Ding" Darling Memorial Drive
Ridge axis
A — Outer
B — Middle
C — Inner
Sub-system
N
0 1000 2000 3000
SCALE IN FEET

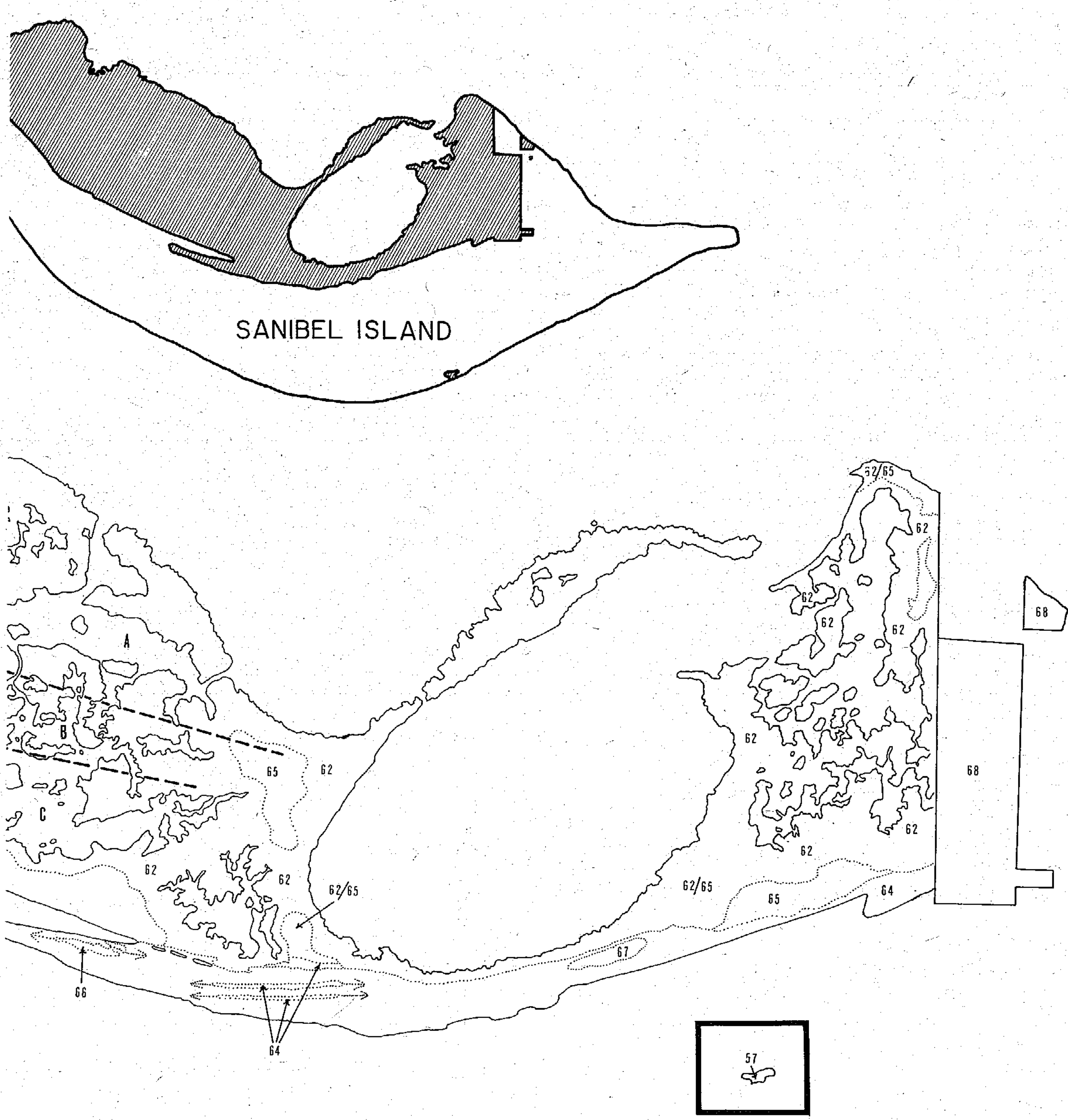


FIGURE 1: SANIBEL - MANGROVE COMMUNITIES

Toward the seaward reaches of this ridge-swale complex the swales are characterized by black and white mangroves ("high" mangrove communities), in addition to a few surviving buttonwoods. In certain areas the soil salinities have become sufficiently high to cause the formation of salterns or "salinas" consisting of open sand areas with sparse stunted black and white mangroves. The next ridge seaward of this zone of incipient salterns is variously occupied by red mangroves, gumbo limbo and remnant cabbage palms. The mangroves tend to occupy the lower slopes of the ridge and are building up a deep, dry litter layer.

It is unlikely that any practical corrective action, such as pumping water from areas south of the Sanibel-Captiva Road, can be undertaken. In any case, it is entirely possible that the defoliation of buttonwoods and the formation of salterns results from the current "drought cycle" which southwest Florida appears to have been experiencing for the past 6 or 7 years, rather than from any artifical lowering of the Sanibel surface and ground waters.

Seaward of this final ridge lies a community of partially impounded black mangrove forest between 500 and 1000 feet in width. The trees are densely situated and of a relatively uniform height at 10-12 feet. Water depth at the time of the survey (late May) was 2-3 inches, but observation of pneumatophore height indicates a maximum seasonal standing water level of approximately 4 inches. A buildup of flocculent material to 4 or 5 inches in places suggests that the impounding effect is strong although drying in winter may allow oxidation and thus limit the depth of deposition. Salinities undoubtedly rise in excess of 70 ppt during the dry season, although recent rains had moderated this to 41 ppt in late May. Black mangroves are overwhelmingly dominant, comprising over 95 percent of all individuals. The northwestern reaches of the natural impoundment formerly stretched west into the section now artificially impounded by the "Memorial Drive" levee.

Seaward of the impoundment edge, a mixed species tidal community occupies a narrow band along the shore of the bay system.

At the eastern extremes of this unit the pattern changes, the natural impoundment expires and the mangrove community ranges from a tidal red mangrove at the bay edge to supratidal, high elevation, mixed small red, black and whites within a distance of 400-500 feet. Numerous mosquito ditches penetrate this community from the bay to the Sanibel-Captiva Road. The upper (inland) 300-350 feet ends of each ditch were largely stagnant at the time of the field survey.

The southern (or southeastern) portions of this tract, between the entrance to the refuge and the outlet of the Sanibel River along a mosquito-control ditch into Tarpon Bay contain significant acreages of mangroves and associated vegetation which are only weakly influenced by tidal action. They are, for all practical purposes, non-tidal. A relatively high ground elevation and a natural berm to seaward combine to restrict tidal influence.

North from Sanibel-Captiva Road the land falls gradually for approximately one-fourth mile in a series of parallel ridges and swales. The ridges are colonized by wax myrtle, Brazilian pepper, sea grape, and occasional cabbage palms and gumbo limbos. Leather fern forms the dominant ground cover. Buttonwoods occupy the low swales with a ground cover of dense <u>Borrichia</u> in places and equally dense <u>Batis</u> in others. The buttonwoods exhibit obvious defoliation as a result of excessive soil salinities to dryness. The absence of <u>Spartina</u> spp. is perhaps a result of predominantly dry soil conditions. <u>Batis</u>, <u>Borrichia</u> and <u>Acrostichum</u> are all capable of surviving in soils of low moisture content.

These 350 foot stretches are probably a minimal effectiveness in controlling mosquitoes. Cyprinid populations were very low in comparison to those existing in the more seaward portions of the ditches. Filling of the upper reaches of the ditches would produce little ecological benefit since the fill would undoubtedly become colonized by Florida holly and Australian pine. These would compete successfully with any mangroves which were planted or which germinated naturally. Consideration should be given to the construction of a series of shallow, roughly circular, lakes incorporating the heads of all the ditches. The lakes would be approximately 3.5 feet MLW maximum depth, with a mean depth between 2.5 and 3.0 MLW. In addition to providing a marked improvement in water quality, they could become a useful recreational boating and fishing facility.

(3) <u>Communities within the confines of the "Darling Memorial Drive"</u>: Three "sub-units" can be easily discussed within the artificial impoundment (culverts beneath the "Drive" connecting the impounded area with the open estuary do not materially modify the impounded nature of this area because they permit so little tidal exchange). The sub-units are:

(a) Large tracts of mangroves in the swale-ridge system lying north of the Sanibel-Captiva Road, particularly, in the western portions of the impoundment.

Except in exceptionally low spots where ponds occur, the mangrove communities of the swales are a mixture of reds, blacks and whites, with reds predominating. Tree heights exceed 30 feet in places, but the average canopy level is between 14 and 20 feet. Deep litter layers are present in most places. Standing water which occurs in a few ditches and ponds is an uncommon feature. Salinities in late May ranged from 8-12 ppt.

The alternating ridges are occupied by cabbage palm, papaya, buttonwood, gumbo limbo, and invading Brazilian pepper. The latter is also encroaching on the higher elevation "dry" mixed red and black mangrove communities. These mangrove communities appear to have become established in earlier times when either fresh water levels were higher than at present or prior to the reduction in tidal penetration resulting from construction of the "Memorial Drive."

(b) Communities fringing open waterbodies. These were formerly fully tidal fringing mangroves with reds dominating. They are now only weakly affected by tides and show signs of stress, perhaps in response to relatively rapid large scale changes in standing water level. This is particularly evident on the landward sides of the open water areas where unusual prop-root branching at a uniform elevation is very evident.

These mangrove communities, as detritus producers and wildlife habitat, no doubt still contribute significantly to the resource base of the impoundment, although their former significance to Pine Island Sound is reduced by virtue of their impoundment. Since they are apparently under stress they probably produce lesser amounts of detrital material than formerly.

(c) Mangroves previously included in a natural impoundment. These occupy the southeastern portion of the "impoundment," seaward of a large mosquito ditch and levee. The natural black mangrove impoundment described earlier extended westward for about one half-three fourths mile into the present artificial impoundment. White mangroves are now more numerous in this portion than in its more natural analog to the east. The increased occurrence of whites may be a reflection of their apparently greater tolerance of hypersaline conditions. Color differences in the May, 1974 infrared photography and shading discrepancies in 1970 series vertical aerials indicate a stress reaction among reds and blacks, perhaps in response to hypersaline conditions or to excessively rapid changes in water level. We recommend careful examination of this and other mangrove communities within the artificial impoundment since they are evidently reacting adversely to an effect induced by the impoundment levees.

(4) <u>Tarpon Bay to Dixie Beach Boulevard</u>: Mangrove communities in the rough triangle between Lady Finger Lake, Dixie Beach Boulevard, and Periwinkle Way are for the most part strongly tidal. A mixed community, dominated in most areas by red mangroves to 25 feet, is characteristic. Tidal penetration, by way of several wide, ill-defined swales, forms an effective mechanical export mechanism to Tarpon Bay and Pine Island Sound for detritus produced within the mangrove communities. The exceptions are a few small areas where black mangroves increase in dominance close to the upland tracts north of Periwinkle Way. Here the parallel ridge system dampens or blocks tidal effect and the established mangrove communities are probably not effective contributors to Tarpon Bay.

North and west of Lady Finger Lake lie the remnants of an old mangrove forest in which large specimens of all three species are found. In the vicinity of Woodring Point very little of the forest area is strongly tidal; a shoreline sandbar has formed and prevents direct tidal access on all but spring tides. Further south the effect of tides is more strongly evident as tide waters penetrate the forest from Lady Finger Lake and adjacent coves with low shorelines.

(5) <u>East of Dixie Beach Boulevard</u>: The only extensive and significant mangrove stand in this area is a 70-80-acre tract of strongly tidal mangroves. Excessive flooding and fresh water during construction of an adjacent development resulted in heavy mortality of trees within the tract, the culvert beneath Dixie Beach Road being inadequate to release the increased input of water.

The tract was formerly a fully tidal community, dominated by red mangrove, although the construction of Dixie Beach Boulevard resulted in a significant diminution of tidal influence. A few surviving white mangroves are recovering and introduced red mangrove seedlings are becoming established. The tract might benefit from the installation of one or two additional culverts along Dixie Beach Boulevard, but a realistic assessment of this must await the re-establishment of a more mature forest.

(6) <u>Miscellaneous Island and Peninsular Communities</u>: This category has been retained to describe the small units of mangroves, mostly of recent origin, which occur in the northwestern sector of the Island between Dinken Bayou and the Gulf of Mexico.

The shorelines of Clam Bayou, Blind Pass, Old Blind Pass, and the small associated island are occupied by tidal red mangrove communities up to 100 feet in width. They are vigorously flushed by tidal action near the mouths of the bayous and less so toward the inner reaches, although daily tidal inundation and export of detritus is sill evident. Few white or black mangroves were observed within these communities.

Landward of the tidal fringing red mangroves a buttonwood-black mangrove-white mangrove complex is encountered in a few locations. These communities are inundated only by high spring tides and are not significant exporters of detritus to adjacent bayous.

Clam Bayou, Old Blind Pass, and Blind Pass exchange with the Gulf of Mexico waters through an inlet at the southwest corner of Sanibel Island. The inlet is generally shallow and guarded by a sandbar except for a narrow channel near the shore of Sanibel. The sandbar at the inlet indicates the magnitude of tidal flushing is probably not great. The sinuous nature of the bayous and blocking of wind by Australian pines and mangroves reduces wind-induced flushing. Density differences caused by evaporation and rainfall will produce some flushing, but the sandbar again will hinder this.

If, as we suspect, flushing is minimal, pollutants from adjacent human activities should be prevented from entering the system and consideration should be given to modifications to increase flushing. If desired, the inlet could be dredged to improve circulation and the old cut to the east could be reopened to improve flushing. These "improvements" would be made in opposition to natural trends and would require maintenance dredging.

Summary and Conclusions

1. The tidal mangroves (62 and 65 of Figure 1) are productive and contribute significant quantities of detritus to the Gulf and to Pine Island Sound. This material is important to the detritus food chain.[15]

Since these mangroves are associated with high productivity which is assimilated via a detritus food web to produce sport and commercial fishes and shellfishes, and since mangroves occur in soils which are comprised of organic peat materials which, when dredged, contribute ammonia, carbon and high BOD, it is concluded that the remaining tidal mangroves be considered for preservation.

2. The mangrove communities in the complex tract east of Wulfert Road are by far the most ecologically significant of any which remain outside the National Wildlife Refuge. In many respects they are superior to the communities in the southeastern portion of the refuge. They are, for the most part, effectively tidal, and must be considered as useful contributors to the resource base of Pine Island Sound, an important sports and commercial fishery area.

3. Probably the most "valuable" mangrove system of the island is the inlet and bay complex within the refuge, external to the "Darling Memorial Drive."

4. Mangroves within the confines of the "Memorial Drive" are under stress of undetermined origin. Nevertheless, they and their associated bays apparently serve as an attractive seasonal bird feeding habitat. They probably no longer contribute significantly to adjacent bay systems. This may be considered a trade-off, whereby a diminution of the support role of mangroves to adjacent bays is mitigated by an increased feeding habitat for bird life.[9]

Within the "Memorial Drive" the inner bays become hypersaline during the dry season and this condition may be responsible for the observed stressed condition of specific mangrove communities. If this is so, the installation of additional culverts beneath the "Memorial Drive" to increase the tidal component is a feasible remedy. We would guess that four additional culverts, positioned where tidal flows are strong to the outside of the "Drive," would provide a strong tidal component to the bay system, thus moderating the dry season salinities.

If the stress is a response to rapidly rising impounded water levels in the rainy season, the additional culverts would also serve to minimize this.

We do not believe that the diversion of more fresh water from upland into the impoundment is a practical or desirable method of moderating salinity. There will probably be little or no available fresh water to be diverted at the height of the dry season when it is needed. Furthermore, the mangroves within the artificial impoundment have not historically been highly dependent upon large volumes of fresh water; they were formerly a predominantly tidal community.

5. Mangroves fringing Tarpon Bay show no signs of adverse reaction to human activities (drainage and urbanization of adjacent uplands). They are subjected to strong tidal action which tends to ameliorate any adverse water conditions emanating from mosquito-control ditches and urban development in the Sanibel River system.

6. The tract of mangroves recently killed by excessive flooding (impounding) is slowly regenerating. Although the mortality was in excess of 90 percent, the survivors are now securely recovered. Red mangrove seedlings re-introduced by Mr. William Byle are becoming established and should continue to flourish if adequate tidal ingress and egress are maintained. An assessment of the advantages which may be gained by the installation of additional culverts cannot be attempted until the forest reaches a more mature stage. Precautions should be taken to ensure that runoff waters high in dissolved nutrients from adjacent developments are prevented from entering this tract. High nutrient levels could promote an undesirable growth of green and blue-green algal mats on the forest floor before a shade canopy can become re-established.

7. The mangrove communities to the north of Sanibel-Captiva Road are unlikely to be greatly influenced by human activities in upland areas. The road forms an effective barrier to any northward overland flow, which would, in any event, be minimal because of the porous soils of the island ridges. Urban development of upland tracts east of Wulfert Road or north of Periwinkle Way could conceivably produce runoff waters of interior quality, but this eventuality can be forestalled by reasonable planning practices, such as maximization of green space, stringent limiting of impermeable surfaces, and detention of initial runoff from impermeable surfaces and lawns.

8. The mangrove communities of Sanibel Island have apparently evolved independently of the interior and upland fresh water system. They do not appear to be dependent upon, nor are they unduly influenced by, surface hydrological events in the interior of the island.

INTERIOR WETLANDS

The interior "wetlands" of Sanibel Island covered approximately 3,200 acres (1944, aerial photos), of which 1,100 acres are presently impacted by roads, canals, and real estate development (1974, tax maps). These wetlands are delineated by a series of old beach ridges which appear to limit lateral surface flow rather completely. The wetlands themselves contain a complex series of low relief (barely discernible from the ground) parallel ridges and intervening swales. All these topographic features are expressions of deposition and erosion by ocean currents as described by Missimer,[16] Shepard and Wanless[17] and El-Ashry.[18]

The relationship between underlying seawater and the fresh water lens on the island has been discussed from the hydrologic and engineering point of view by Boggess[19] and Provost[20], while the very complex matter of long-term fluctuations in sea level have been discussed by Bruun[21] with respect to erosion of shoreline and Provost[22] with respect to coastal development.

Water quality determinations were made at various locations on the island by Boggess[19] and Schreiner.[23]

All these accounts give an impression that water levels in the interior were subject to wide fluctuations over short, as well as long, time periods and that these fluctuations were related tc (1) rainfall periodicity and amount, (2) occurrence of over-drainage when storage was lost due to natural break-out of the impounded waters, and (3) cyclic changes in sea level.

Narrative accounts[24,25] of the physical appearance of the interior of the island during earliest settlement all describe broad, open vistas of "grassland" broken at intervals by clusters and rows of cabbage palms. Viewing the island now, it is evident that there has been a significant change in vegetation which is discussed at length below. A widely held assumption is that alteration of surface water storage accompanying mosquito control[26] has been responsible for the changes. We believe that fires, farming, and more recent invasion by exotics have contributed greatly to this change and all these factors are part of a complex series of environmental impacts on the natural system. Each event, in effect, set the "machinery of change" in motion and these changes are still in progress.

In reviewing the probable past history of the interior lowlands, it should be made clear what is meant by us when we mention wetlands. Wetlands of Sanibel Island are those areas which are subjected to permanent flooding or prolonged periods of soil saturation sufficient to permit development of "indicator" plant and animal associations. Thus, to qualify as wetlands, Sanibel Island interior lowlands should have, as plant dominants, at least some of the plant species found to be characteristics of South Florida coastal wetlands generally. Concurrently, it would be expected that at least some aquatic vertebrates and invertebrates would also occur there. The word used by biologists to define the periods of flooding or soil saturation is "hydroperiod" and, for South Florida generally this may persist for the duration of the rainy season in areas having little or no watershed runoff, to periods of 10-12 months in the southern Everglades where the watershed is very large.

On Sanibel Island, where rainfall amounts seem to differ substantially from comparable areas of the mainland[25], we might expect the hydroperiod to differ in duration from nearby mainland areas.

PRE-DEVELOPING CONDITIONS

Not much is known about the pre-drainage character of the central lowlands of Sanibel Island now generally known as the interior wetlands.

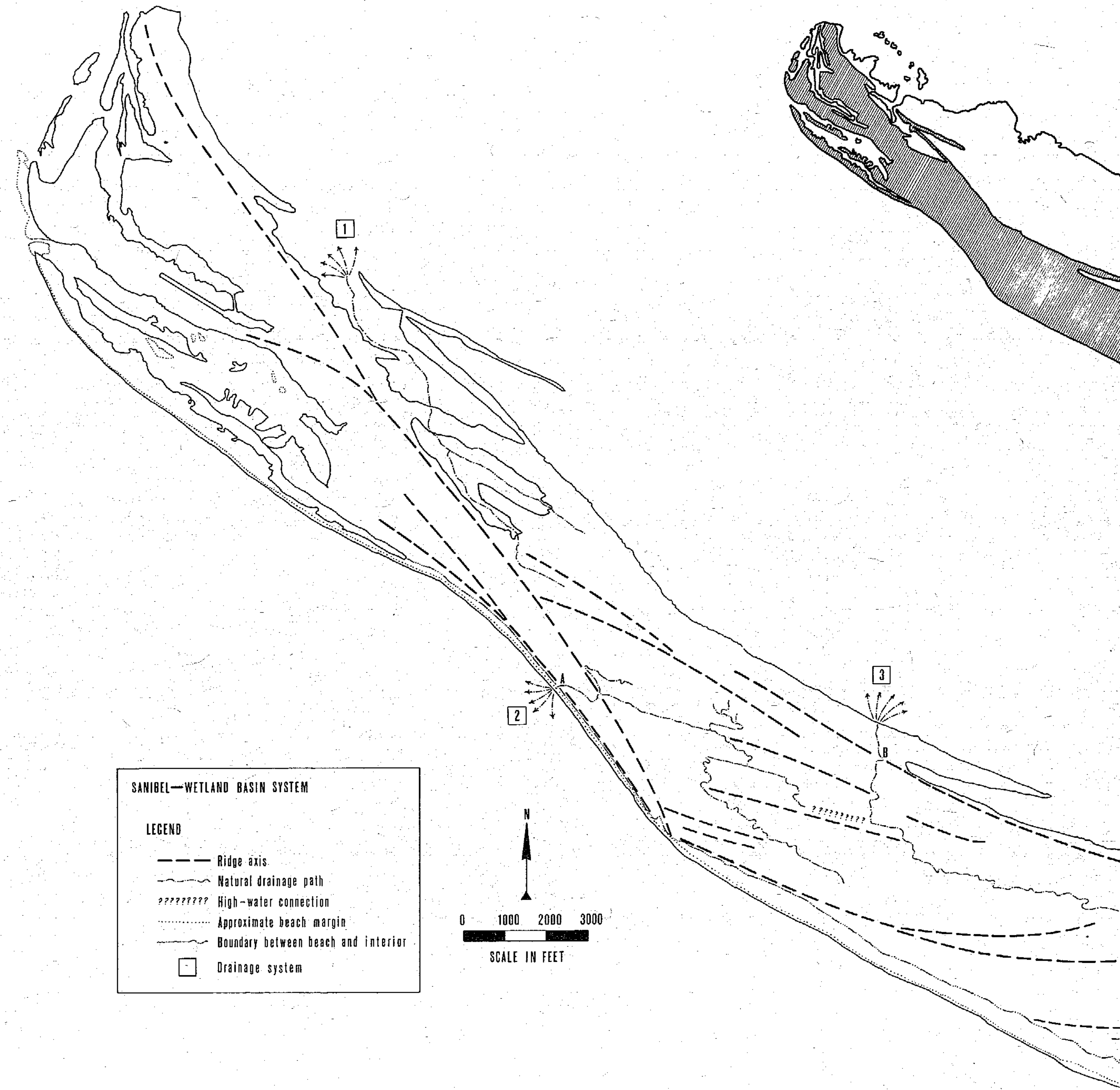
Although the interior lowlands of Sanibel Island have been treated as a single management unit for purposes of mosquito control and flood control generally, we believe there is evidence (1944 aerial photos) that there once were at least four separate collector or basin systems (Figure 2), each of which had its own intermittent interior stream and outlet to tidewater, prior to modification.

Subsystem 1 was confined on the east, north, and south by old sand ridges, but no such ridge blocked accumulating rainwater there from flowing west into a series of interconnected ponds which formed the exit to tidewater for this system. Because there was no barrier "across the grain" near tidewater, this system probably drained earlier than any of the others and, conversely, became hypersaline sooner than the others during the drought. This pattern remains unchanged to the present and should have the fewest freshwater indicators present as a result.

Subsystem 2 appears to have headed in the region just west of the present Rabbit Road and the main Gulf beach ridge and extended west to its outlet through the beach ridge at Point A in Figure 2. Since its outlet crossed an active beach, it probably was virtually a self-sealing system as interior head pressure declined with draw-down.

Subsystem 3 appears to have originated near the main east-west ridge (route of the Sanibel-Captiva Road) about 1.5 miles south of Tarpon Bay in a z-shaped lake system and extended west and then north, to empty into the mangrove marsh via an old outlet through the ridge about 1.5 miles west of the present junction of Rabbit and Sanibel-Captiva Roads (point B). There is a hint, on the 1944 aerial photography, that there was a high-water connection or intermingling of impounded waters of systems 2 and 3 before drainage. This and the following system are probably the oldest water storage areas from a geological standpoint.

Subsystem 4, by far the largest of the systems, originated behind the Gulf beach about 1 mile west of the present-day Tarpon Bay Road and extended eastward in virtually a straight line to the extreme east end of the present-day Gulf Drive where it cut an outlet through the beach (point C). As with Subsystem 2, this would have been a self-closing system; its outlet would have filled with drifting sand by littoral drift, thus reducing the chance for additional loss of fresh water until such time as heavy rains once again filled the basin forcing another break-out.


1
2
3
A
B
SANIBEL—WETLAND BASIN SYSTEM
LEGEND
Ridge axis
Natural drainage path
High-water connection
Approximate beach margin
Boundary between beach and interior
Drainage system
N
0 1000 2000 3000
SCALE IN FEET

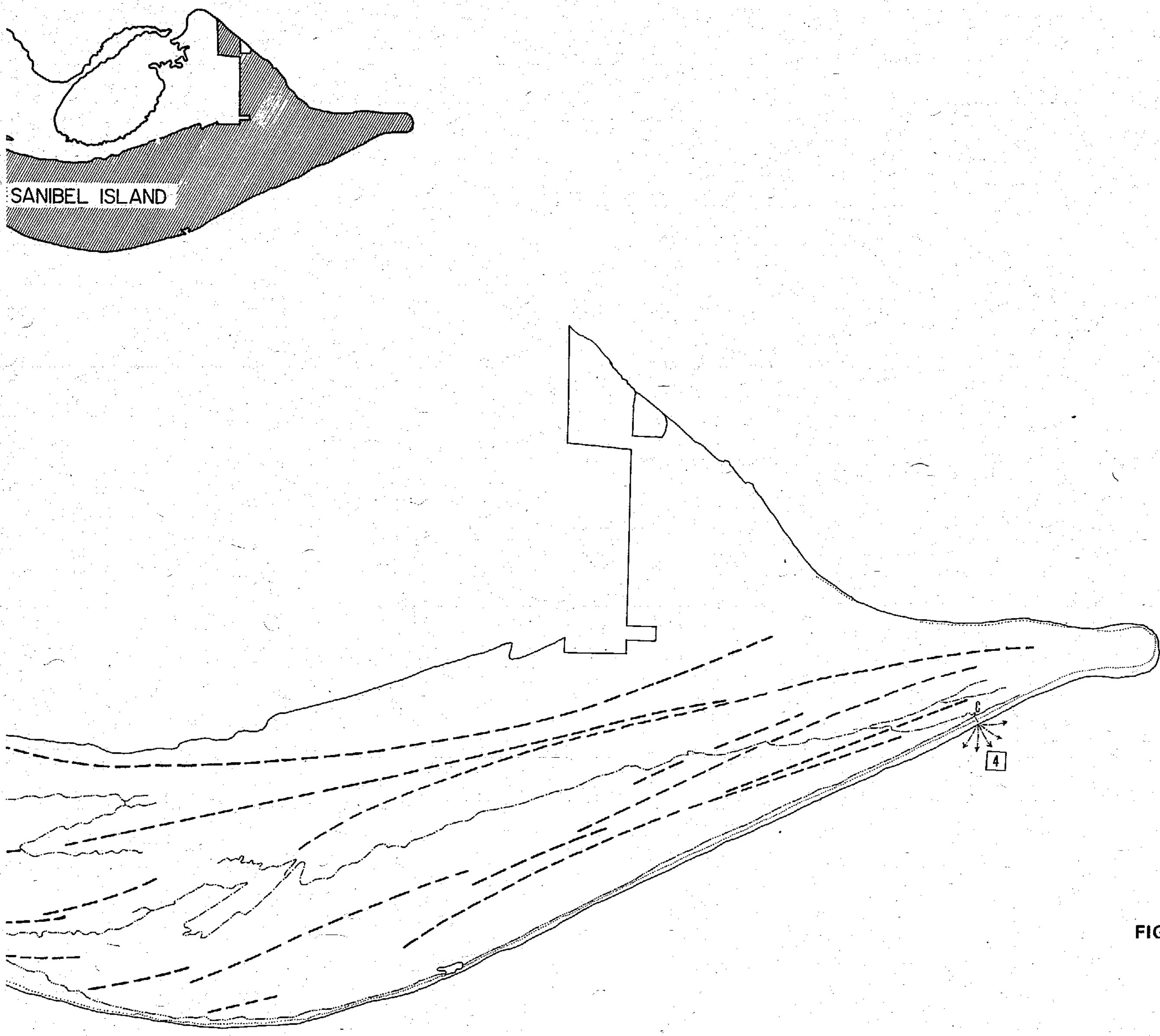


FIGURE 2: SANIBEL - WETLAND BASIN SYSTEM

The quantity of storage in the interior, required to breach the Gulf beach ridge, is of considerable interest to us. In that context, Provost is quoted as follows:

> When summer rains raised the basin water high enough, the beach at the mouth of Sanibel Slough, east of what is now Periwinkle Way, would be breached and a small Mississippi River would flow into the Gulf of Mexico. In 1949 we calculated this water loss at 2000 acre-feet, or 700,000,000 gallons. With all this head of water gone, the surf would rebuild the beach, so that by the next June the dry basin, virtually devoid of minnows, renewed its storage of rainwater while hatching billions of mosquito eggs into larvae with hardly a threat from their greatest potential enemies.[20]

It interests us that Provost does not mention that abnormally heavy rains caused this wash-out. It gives a clue, in the absence of measured rainfall amounts, that such wash-outs were not uncommon prior to drainage. We have more to say about this below.

In addition to the four systems described above, there are a number of smaller rainwater catchment areas between "younger" ridges behind the present Gulf beach. One of these lies just behind the beach in the vicinity of the dead end on Gulf Drive and has its outlet(s) in what is now called the Perry Tract.

According to our best estimates, prior to development, Subsystem 2 contained 588 acres of low ridge and swale catchment and storage area. Subsystem 3 contained 1,240 acres and Subsystem 4 contained about 1,760 acres. These have been physically reduced in size to 425 acres, 941 acres, and 1,027 acres, respectively, by development and Subsystems 2, 3 and 4 have been made one by dredging of the Sanibel River channel and numerous tributary ditches.

In addition, the present water management system is designed to prevent accumulation of water sufficient to break out over the beach while preventing the over-drainage that such "blow-outs" entailed. The effect on interior water storage hydrograph or storage curve has been to truncate the highs and lows in water level while preventing intermittent, early rainy season ponding which leads to optimal mosquito-breeding conditions. Furthermore, the presence of at least some fresh-to-brackish water in the channels within the system during drought water provides refuge for residual populations of mosquito-eating fishes.

During pre-drainage times the storage curve would probably have risen very slowly during May, June, and July because of spotty, generally light rains.[19] In August, September and October the generally heavier rains fall on a reservoir whose storage capacity has been reduced substantially by fall high tides.[22] If rains were of sufficient magnitude, which we believe they were nearly every year, there was wash-out. If less substantial, the rise in interior storage would terminate in mid-to-late October and then decline through seepage and evapotranspiration losses until the next rainy season. The actual mechanics of this annual pattern are discussed elsewhere in these reports.

Proceeding on the assumption that there actually were four major catchment systems on the island prior to development, and using Subsystem 4 as an example, we have arrived at a rough indication of impoundment depth and storage possible before breaking through the beach. To do this we use the ratio between 2,000 acre-feet of discharge described by Provost[20] and our estimate of 1,760 surface acres in predevelopment Subsystem 4. If the system were a shallow tray with perfectly flat bottom, we might assume that the 2,000 acre-feet of discharge would have raised interior storage about 1.1 feet. In fact, the ridge and swale topography of the interior lowlands complicates this estimate. Something closer to the actual rise may be estimated by examining the implications of an observation during July (John Clark, personal communication) that a 2-inch rain resulted in a 10-inch depth of impoundment in swales. Since this rain must have been very nearly the first of the rainy season, and coming as it did "on the heels" of an exceptionally dry period, we believe it is likely that most of the rain which fell on the dry sandy ridges quickly ran off to the adjacent swales. Although, admittedly, a simplification, the ratio of rain to impoundment depth of 2 to 10 inches (i.e., 1:5) strongly suggests that there are five times as much ridge surface as swale area in Subsystem 4. Going further, if we assume that the ridges are 12 inches higher on the average than the swale bottoms, we arrive at 1,408 acres of ridge at about +3 feet relative to MSL, and 352 acres of swale, whose bottom elevation was about 2.0 feet relative to MSL. In a basin of this configuration whose bottom elevation according to Provost varied between 10 and 18 inches relative to Mean Low Water, or about 2 to 3 feet relative to Mean Sea Level, we have calculated that the runoff from a 2.4-inch rain over the entire 1,760 acres would produce 350 acre-feet, or enough to fill the swales level with the tops of their adjacent ridges. Beyond that, it would take 12 inches of rainfall, assuming no losses, to raise the level of Subsystem 4 to full pool at elevation +4 feet MSL. According to these very simplistic calculations, we propose that the pre-drainage Subsystem 4 would hold up to 14.4 inches of rain before blow-out.

Examination of the U.S.G.S. "topo" sheets show several places along the beach ridge which are lower than 5 feet. Almost all these areas are present or former locations of freshwater wash-outs. The Perry Tract has two drains, the westernmost probably the oldest, which are presently blocked by a fully developed beach formation.

Today, Subsystems 2, 3, and 4 have been made into one collector-drainage-mosquito control system by excavation of the Sanibel River canal and a series of tributary ditches which divert most of the surplus fresh water to Tarpon Bay.

In order to understand the existing drainage system and its ecological implications, we turn to Boggess.[19] Among the many aspects of island hydrology described was an estimate (p. 27) of 600 million gallons of discharge through Tarpon Bay and Beach Road outlets (500 million and 100 million gallons, respectively) following heavy rains, averaging about 24.5 inches at two gauge stations (8 inches in August and 16.5 inches in September, 1971). This provides some estimate of rainfall required to produce the 1949 washout[20] of 700 million gallons.

INTERIOR LOWLAND SOILS

The accounts by Missimer[16] and Boggess[19] of surface and sub-surface soils and rock formations on Sanibel form an excellent basis for the general consideration of water supply, hydrology and engineering, but omitted, except in passing, reference to surface deposits of calcium carbonate soils of biological origin called marl. We found marl to be an important constituent of swale-bottom soils and of widespread occurrence in Subsystems 3 and 4. While they are, quantitatively, not particularly impressive, we believe they have extraordinary ecological significance.

In examining canal bank exposures for marl deposits we also found one well-developed lens of semi-consolidated limey material which greatly resembles the hardpan found in acid sand country of the adjacent mainland. Until we can prove otherwise, this may prove to be an example of "beach rock" mentioned by Missimer, but we believe it to be true hardpan derived from precipitation of organic material and "migrating" minerals in solution at the contact between the water table and overlying oxygenated sands. The "type" exposure is located at the junction of Island Road and Tarpon Bay Canal on the west bank of that canal. The exposure is apparently discontinuous, occurring under the sandy "buttonwood" ridge, but is absent from under the adjacent marl-bottomed swales. If this is true hardpan, then it may represent the long-term position of the water table during the dry season of pre-drainage times and thus an interesting reference point for discussion of future water management because it would suggest that the water table seldom fell out of direct contact with the marl of the swales.

The presence of marls deserves considerable attention. Apparently most of the marl soils of South Florida, including surface marls of Sanibel, are of bio-chemical origin and are formed through calcium carbonate precipitation by a complex, shallow-water microflora dominated by blue-green algae. Such soils are formed in shallow water under conditions of intense sunlight, high temperature, and rapidly (i.e., daily) fluctuating dissolved oxygen and pH. Such conditions would have prevailed in open savannahs dominated by *Spartina bakeri*. Marl formation does not take place in deeper, shaded water. The blue-green marl producers are replaced by green algae in shaded locations such as those now developing under the tree canopy invading the Sanibel swales.

The fundamental process of marl formation has been described recently by Gleason and Spackman[28] who also quote pertinent literature. Over large areas of South Florida marl deposits of both fresh water and brackish water origin are widespread, as indicated for Dade County.[29] The importance of these to agriculture and to natural plant distribution can be grasped by reading Department of Agriculture soil surveys[30] and Craighead.[31] Such soils are very complex from drainage, salt relationship, and nutrient balance standpoints, and one of the few papers discussing chemical and physical management of marl soils is provided by Volk and Orth.[32] Their comment (Abstract, p. 1) regarding behavior of nitrogen in freshwater "Perrine marl" which has been saturated by salt water is of considerable importance to anyone considering disposal of nitrogen-enriched effluent on Sanibel Island, where the marls probably are also of freshwater origin, but which are subjected to periodic salt intrusion.

> The pH of the sodium saturated soil was sufficiently high that normal nitrification following application of ammonium sulfate equal to a band rate of 100 pounds of N per acre was halted at the nitrate stage, with net accumulations up to 192 ppm of nitrate nitrogen but negligible nitrates."

On p. 21 they state the problem more succinctly as follows:

> The potential for accumulation of toxic amounts of nitrite following salt inundation and leaching is obvious, with urea being the least desirable N source to be used when such a potential exists.

The toxicity mentioned is assumed to apply to agricultural crops; that is the milieu in which Volk and Orth work. But their comments may be equally important for future wetland vegetation on Sanibel, should these areas be used for reclamation of sewage effluent. From this, we would urge extreme caution in using the marl-rich areas of the interior lowlands for sewage disposal so long as salt intrusion is a potential problem.

Finally, Harper[33] indicates that *Spartina bakeri*, one of the wetland indicators formerly dominant on these lands, is associated with "calcareous soils" which we interpret as marl or mixtures of marl and sand.

In the absence of time to map the aerial extent of these marls we were forced to make a few assumptions. One of these was that marl formation is a slow process and that marls would be best developed in the geologically older parts of the island. That would be systems 3 and 4 of the interior. A second assumption was, following the prior reasoning, that marls would become progressively less important in the more recent swales of system 2 and in swales near the beach ridge. Our travels on the island appear to substantiate this pattern with marl being visually absent from the beach ridge depressions.

The point of such emphasis on marl, alone or mixed with sand, lies in its ability to seal otherwise porous soil, thus impounding surface waters and, once wet, to retain moisture. Experience with marl as a sealand was gained during construction of shrimp culture ponds on an elevated, crushed rock base at Florida Power and Light Company's Turkey Point electrical generating plant site in Dade County. We learned that a four-inch thick layer of marl effectively sealed such substratum against leaks in ponds having average depths of three feet and maximum depths of six feet.

There are many swales in the Sanibel interior that have marl or sandy marl deposits of equal or greater thickness and we have seen these areas covered immediately after early rainy season showers. It is our view that such marls were extremely important in maintaining the hydroperiod and providing shallow but intermittent ponding prior to being ditched, as well as maintaining soil saturation between showers. Such deposits are linear, being located in the swales. Thus any ditching which tended to cross such swales and draw off the temporary ponding of May, June, and July would tend to reduce the aquatic character of the swales, if not the soil moisture. In the latter context, such marls might be kept moist, not necessarily saturated, by capillarity if the underlying ground water is in close contact. This would tend to soften the impact of drainage through ditching on plants requiring higher degrees of soil moisture, but the tendency then would be away from true wetland to a marginal upland water budget favored by plants not geared to standing in water (e. g. Brazilian pepper versus Spartina).

THE LEAKY SAUCER THEORY

The presence of marl in swales alternating with sandy ridges throughout much of systems 3 and 4, calls to mind a leaky pan or saucer resting on a sand bed having greater or lesser water-holding capacity. Although greatly over-simplified, that is, generally ignoring the hydrology of soils under varying rainfall conditions, the theory goes as follows.

The interior basins are basically porous sand with water table at a minimum level in spring. On top of this "dry" sand are water-retaining marly areas in a ratio of approximately 5 acres of exposed sand to 1 acre of marl. During spring drought the water table is at a distance below the surface so that the tops of the sand ridges are dry and, for a time, water repellent. Later they absorb much water.

Add early rainy season showers at a weekly or greater intervals and observe that there is immediate impoundment in the marl-bottomed swales. Continue observing and one sees loss of impoundment depth; some water being lost to evaporation and plant transpiration while some seeps into the adjacent ridge and downward toward the water table. If the rains are of minor character this lateral and downward seepage has only a minor effect on ground water level. If subsequent rains are delayed, as is commonly the case on Sanibel, the marl saucer drains, but being marl, the soils stay moist and wetland plants begin their annual growth period.

In due course a second and third rain falls. If of minor character and widely separated in time the above process is repeated with little increase in ground water level below but with repeated inundation and drying of the swales. During pre-drainage times each inundation of the swales would permit invasion of brood stock of fishes and other aquatic organisms as well as hatches of insects having aquatic larvae.

Finally, at some time each year, perhaps in late August, tide levels around and under the island begin to rise. This causes a rise in the ground water and automatic loss of potential storage capacity in the sand bed under the saucer. At the same time rains increase in frequency so that the swales remain flooded and seepage downward from the ridges and impoundments is greater than loss of water to the atmosphere. With that, ground water is recharged abruptly and becomes one with the swales. From then until the end of the rainy season the "leaks" in the "saucer" are closed, not to be opened until the following winter.

Two factors probably have major influence on what happens to this filled system. Under pre-drainage conditions there may have been a rather rapid adjustment in island groundwater downward sometime in late October and November, for it is known that the South Florida high-water levels of September and October fall off rather rapidly as the prevailing southeasterly winds of summer are replaced by powerful northeasterlies of October and, in rapid succession, by northwesterlies (i.e. polar fronts) of November and December. Such wind shifts tend to push the summer's accumulation of fresh water from South Florida coastal marshes which is replaced rapidly by high salinity water of adjacent Gulf. On Sanibel, where there is no large tributary watershed contributing runoff to the island interior, we would expect a rather rapid reduction in ground water level then as a result of tide height reduction and wind-sweeping losses of surface water. This might shorten the winter interval when the marl swale impoundment and ground water were contiguous. If no beach wash-out occurred in the hypothetical year this water level adjustment should not result in immediate drought, just a "slump" from +4 to +3 foot of storage.

Under present drainage conditions, the lower-than-natural level of drainage control structures would have been draining off "surplus" waters from the beginning of the time that storage levels overtopped those controls. This could, when coupled with the falling tides and pushing winds of October and November cause an abrupt end of the hydroperiod or at least reduce the contact between the swale waters and ground water. This, in turn, would quickly permit evapotranspiration to remove remaining surface waters.

With the system intact, the wetland character of the interior, including shallow surface flooding of the swales probably lasted from June through December. With drainage, these conditions probably prevail only in smaller, unditched areas.

INTERIOR WETLANDS AS HABITAT

Judging by word-of-mouth reports there were no extensive areas of permanent fresh-water habitat on Sanibel Island prior to settlement. A few natural ponds can be seen scattered about the island in 1944 aerial photography, but we believe the recent profusion of lakes, borrow pits, ditches, and drainage channels in the wetlands has greatly increased lake habitat. In addition, while the 1944 photography clearly shows a permanent channel where the Sanibel River now exists, even this has been increased by dredging. Under such conditions we would expect an increase in freshwater aquatic plants and animals as well as a significant increase in permanent water edge which has direct bearing on wildlife use of the area.

On the basis of the above generalizations, and in light of our experience in similar areas (e. g., Cape Sable marshes) in South Florida which have not been extensively altered by man, we have concluded that the aquatic fauna of predevelopment Sanibel Island interior wetlands had an overwhelming preponderance of species capable of withstanding alternating wet-dry conditions and considerable tolerance to low oxygen and salt, the latter important if winter drying drove these animals to the adjacent bays. We expect that the insect fauna then, as now, was dominated by saltmarsh mosquitoes. Aedes sollicitans and A. taneorynchus. There probably were larger numbers of biting flies, family Tabanidae, then than at present. Drainage has reduced the habitat of all these. The dragonfly population probably was large but restricted to fewer species such as Libellula auripennis, and Cannacria gravida, which easily tolerate salinity of 15 to 20 ppt as larvae.

As it happens, areas where intermittent ponding and drying are the rule are also prime producers of marsh mosquitoes and a few species of specialized marsh fishes, such as Gambusia affinis, Fundulus confluentus, Poecilia latipinna and Cyprinodon variegatus. Not incidentally, these fishes are major forage species for highly prized wading birds such as white ibis and most of the herons and, when driven to adjacent bays by receding water levels of fall and winter, of numerous sport fish including tarpon, snook, ladyfish, snappers and crevalle jack. It is probably safe to assume that abundance of such small fish is directly proportional to the acreage of flooded shallow marsh available to them, and it is the presence, beginning early in the rainy season, of extensive marsh ponding which permits maximum numbers of these fishes to be produced. It is also important in an ecological sense if not strictly in a biological sense to consider these small fishes as "annuals." There is considerable evidence, of an empirical nature, which indicates very high winter mortality and resultant small brook stock to begin each new spring crop even though they have a life expectancy potential of two or more years.

Fishes would probably have been the same species as are presently found on the island, but freshwater centrarchids (i.e. sunfishes) such as largemouth bass, Micropterus salmoides; bluegill, Lepomis macrochirus; spotted sunfish, or shellcracker, Lepomis punctatus and redear sunfish, Lepomis microlophus, would have been far fewer in number while mosquitofish, Gambusia affinis; marsh killifish, Fundulus confluentus; sheepshead minnow, Cyprinodon variegatus and rainwater killifish, Lucania parva would also have flourished in greater numbers. Other Fundulus species would also have been common, passing seasonally from bay to interior waters, as were the sailfin mollies, Poecilia Latipinna. Spotted gar, Lepisosteus platyrhincus, and least killifish, Heterandria formosa, which are found on the island now in small numbers, probably were never abundant.

The above discussion points out the difficulty revolving around management of marshes where the same factors which tend to favor small, desirable fishes and many showy birds also guarantees maximum production of mosquitoes and a few other obnoxious insects having aquatic larvae. It is a dilemma that requires very careful consideration. It may be the most critical decision to be considered.

If the future planning of Sanibel Island involves raising the water table, there will be a reinstatement, at least in such managed areas, of the conditions which fostered larger aquatic insect populations and greater number of opportunistic killifishes, all of which thrive on alternating flooding and drying of the marsh.

The value of edge vegetation in wetland pond situations is usually very high. On Sanibel natural ponds are generally surrounded by Spartina bakeri, buttonwoods, leatherferns, occasional red mangroves, and a number of other grasses, shrubs, and vines. In addition, cattails, Thypha sp. are relatively common and stonewort, Chara hornemannii, occurs in greater or lesser abundance wherever water is clear. Widgeon grass, Ruppia maritima, is also widespread in coastal brackish marshes, as well as in the Sanibel River and older development waterbodies less than three feet deep at low water stage. Ruppia is of special interest because of its wide tolerance to high turbidity levels, as well as to salt. Duckweed, Lemna sp., has been observed at numerous locations in the river, as well as in ponds which are over-enriched.

While Lemma is valuable as food for waterfowl, its presence generally indicates poor mixing and high nitrogen inputs. Chara is used as food by waterfowl and offers habitat for fish-food organisms, but because it grows so rapidly may produce anaerobic black muds resulting from decay of shaded-out lower stem masses. It is an indicator of hard water where calcium is abundant. Although Chara is best developed in shallow, clear water, it can grow profusely in clear 20 foot-deep lakes. Ruppia maritima seeds and foliage are heavily utilized by waterfowl and may be the single most important aquatic bird food plant of coastal South Florida. Ruppia is common in brackish bays, saline marshes, and freshwater areas up to 8 or 9 feet in depth.

Shore and ditch bank vegetation includes wax myrtle, Myrica cerifera, which has some value for wildlife being used extensively by red-winged blackbirds for nest sites. Where buttonbush, Cephalanthus occidentalis, occurs it is used as food by mallard and other ducks as well as providing excellent roosting cover. Primrose willow, Ludwigia Peruviana, which has seeds used by waterfowl and willow, Salix caroliniana, offer cover and nesting areas. Gallinules feed extensively on willow flowers (T. Alexander, personal communication).

The exotic plants, castor bean, Ricinus communis; Brazilian pepper, Schinus terebinthifolius, and Australian pine now occur frequently along canals and the River. Burkhalter et al. indicated no wildlife value for them, but it is now known that raccoons, opossums, and wintering robins, Turdus migratorius, consume vast quantities of the Brazilian pepper berries in season. Anhingas nest in waterside Austrailian pines and many water birds use them for roosting and feeding perches. Doves, both ground dove, Columbigallina passerina, and mourning dove, Zenaidura macroura, feed on the fine, winged seeds of Australian pine, as do migrating American goldfinches, Spinus tristis.

Herbs, vines, ferns, and various grasses are everywhere abundant in the swales of the interior wetlands combining to form cover so dense that shy or secretive animals are difficult to see. The salt ponds of the island may be surrounded by salt grass, Distichlis spicata. Where it occurs one may reasonably expect to find the cut tunnels of rice rats, Oryzomys palustris, which may share space with the cotton rat, Sigmodon hispidus, in the drier sections of the interior wetlands. The latter are especially abundant in the overgrown farm lands of Sanibel and form one of the major items of food for red-shouldered hawks, Buteo lineatus, which nest in tall Australian pines (personal observation). Wetlands are important habitat for other food animals of the same hawk, which consumes leopard frogs, Rana pipiens sphenocephala; green tree frogs, Pyla sp. and small snakes and lizards.

Animals of the interior wetlands are mostly planktonic, nektonic, or associated with emergent plants (the Periphyton and aufwuchs communities). The general paucity of benthic organisms in the Sanibel River probably reflects accumulation of organic sediments with low bottom dissolved oxygen levels and high levels of hydrogen sulphide. Considering the poorly flushed character of this waterway we would expect such conditions to arise naturally. The leaf fall from marginal vegetation is very heavy and acts as "green manure." When large quantities of sewage effluent are added to such a system in the absence of some mixing force one should not be surprised over total deoxygenation. The problem is complicated by the virtual sheltering from wind with which to circulate the deep water. This is aggravated by steep banks, narrow width of the canal, and overwhelming vegetation. The later also screens the sun's rays preventing light penetration in an already dark water. There are some other waters, notably in mosquito ditches, which are virtually in the same condition. They are usually less of an environmental hazard because they are flushed, at least periodically by tides or upland runoff. They are usually shallower than the river and they lack the control structures which so greatly aggravate the situation in the river.

Common aquatic insects in the interior included water beetles, Haliplus; backswimmers, Plea sp.; water scorpions, Ranatra sp.; midges, Tendipes; several damselfly species and seven species of dragonflies of which Libellula auripennis was dominant. The larval stage of the latter has been found by us to thrive in mangrove marshes where salinity averaged 18 ppt and where the nymphs were exposed to the air by falling tides of winter. At those times the nymphs cling to the concave under surfaces of whole mangrove leaves, apparently surviving quite well for days at a time in a saturated atmosphere made possible by capillary movement of sub-surface water through the peat soil. All the dragonflies seen by us are common in calcium-rich waters of coastal South Florida, returning to the sea to spawn. Large numbers of adult blue crabs are stranded by receeding surface waters of the southern Everglades area whenever there is a drought. They simply cannot move overland to open water once their "home" ponds go dry. This seems most likely to happen in Spartina bakeri and Distichlis spicata grass marshes which are typically covered with shallow strand and pothole ponds only a few inches deep just as are found on Sanibel.

Among the chordates we observed raccoon, Procyon lotor, in fresh water areas, but they and their signs seemed more common in the marginal wetlands and mangroves. Green tree frogs seemed most abundant in cattails while leopard frogs, Rana pipiens, were observed in many wet areas, particularly in Bacopa growing in damp soil of the deeper swales.

The occurrence of bluegill, shellcracker and largemouth bass nests in the canal along the southern side of the Bailey Tract and at a few locations in the western reach of the Sanibel River indicates that these areas have good freshwater conditions throughout the dry season and pollution effects have not yet moved "upstream" from the developed areas.

The fauna of the interior freshwaters is relatively poor compared to the mainland and this reflects the insular position of Sanibel Island, plus a somewhat transitory nature of the freshwater system. Few primary freshwater fishes (only the centrachids and gar) exist, and the centrachids may have been brought to the island by anglers. As one would expect, the tolerant euryhaline species are dominant, complemented by normally marine species which can invade freshwaters rich in dissolved solids.

The area west of Tahiti Drive is generally more saline and the flora and fauna reflect this salinity increase. Mangroves become dominant shoreline plants along interior shorelines and estuarine invertebrates and fishes become more numerous. The inch-long caridean shrimp, Palaemonetes pugio and P. intermedius, occupy algae and Ruppia maritima beds in this area.

Prior to drainage, seepage of fresh water from the interior probably prolonged the fresh-to-brackish character of marginal wetlands and permitted growth there, on ridges, of such nominal freshwater plants as cabbage palms, leatherferns, etc. With drainage this freshening tendency would have been reduced so that halophytes would spread further inland and, in extreme drought, soil salt would have become severe enough to kill plants and create plant-free salterns. Our recent observations, made during drought conditions, showed many signs of plant stress in the marginal wetlands and the soil chloride determinations of Alexander illustrate the severity of effect of this salting on vegetation.

The vegetation of the marginal wetlands described below is dominated by salt-tolerant species while the fauna there is limited in species richness and consists of insects and fishes which are noted for tolerance to environmental extremes. Blue-green algae dominate in the shallow, seasonally flooded to wet soils of the marginal wetlands. These algae form mats 1 to 2 centimeters thick, especially over the saline sands in bright, sunny situations. Anaerobit conditions commonly exist under such mats. Shallow permanent ponds, up to 2 feet deep in scrub mangrove areas, often have deposits of brown to purple "liver" muds up to five inches thick which are prodigious producers of hydrogen sulphide. Seasonal flooding to depths of 2 to 10 inches is common in the higher elevations. If such flooding is in open, sunny locations where Batis grows there will be no liver mud because of dry-season oxidation of accumulated organics.

Only a small number of species of fishes and invertebrates occur regularly in these shallow, changeable habitats, but they often occur in very large numbers. The small sheepshead minnow, Cyprinodon variegatus, is the dominant fish in such areas. It can tolerate salinity ranging between 0 and 140 ppt.[35] It over-winters in the "floc" ponds within the black mangrove-buttonwood zone of the high tidal marsh. Males in iridescent nuptial blues and orange may be found in such ponds beginning in December; breeding continues into May or June. The young are quick to colonize newly flooded areas, particularly in the Batis and Salicornia zone and ranges from there onto the algal mat of the salterns or salinas during the rainy season. Its "preferred" upper salinity range appears to be about 60 ppt.

The dominant insect of the chemically changeable, seasonally flooded marginal wetlands is the water boatman, Corixa sp. of the family Corixidae. It is a true bug of the order Hemiptera, but unlike most such bugs it has no pronounced, external piercing mouthparts and is not predacious. These insects are ooze feeders subsisting on algae, protozoans, and detritus gathered by the first pair of legs modified for scraping. It does have hidden small piercing mouthparts called stylets with which it sucks juice from algal filaments. Being air breathers, they make constant trips to the water surface to capture a bubble of air which envelops them and imparts an overall silvery sheen to their bodies as they quickly return to the bottom. They winter as adults, laying their top-shaped eggs on plant debris. Adults take wing and fly to new areas at the beginning of the rainy season. At such times they are attracted to lights and form piles of helpless individuals on window ledges and porch floors.

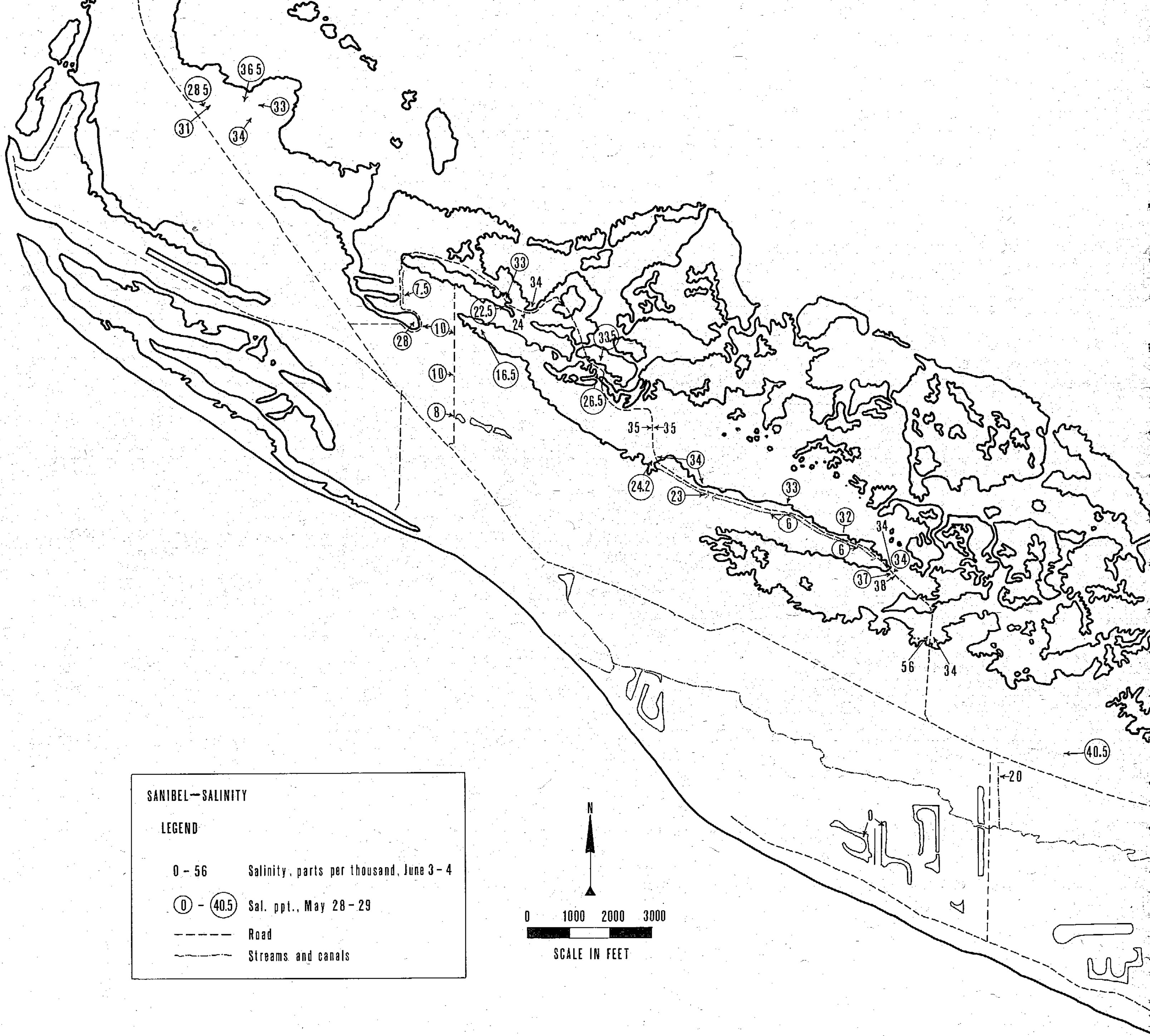
We believe they have great significance as food for numerous birds and animals, although this has not been documented in Florida. Adults and eggs are collected in great numbers and used as food by man and birds in Egypt and Mexico. They have been imported into England for use as food. They have also been utilized as food for young game birds in wildlife management programs. Water boatmen seem to be the brackish-water counterpart of salt-marsh mosquitoes found slightly higher up on the marsh gradient in even more transient aquatic habitat. We have not seen them occurring in large numbers with mosquito larvae.

LOWLAND AQUATIC FAUNA

At the time of our visits to Sanibel Island the interior aquatic milieu was restricted entirely to borrow pits, development lakes, mosquito or drainage ditches , and the "Sanibel River" system. Within the tract bounded on the east by Beach Road, on the north by the Sanibel-Captiva Road (S.R. 867), on the west by Rabbit Road and on the south by the Gulf Beach Ridge, salinities ranged between 0 and 4 ppt (seawater = ca 35 ppt) which is well within the upper limit of 10 ppt tolerated by many fresh-water organisms of South Florida

Water east of the Sanibel Causeway-Beach Road dividing line was uniformly saline to the water control at Beach Road where salinity of 31 ppt was measured. Salinity of 4 ppt west of the control structure indicates the effective closure of the Sanibel River at this point by the closed structure. A slight leaking through the structure attested to a modest head of water within the river.

Higher salinities were encountered around the periphery (Figure 3) of the above described interior sector as in ponds near the Perry Tract, in ponds within the Dunes develop-


36 5
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38
56
34
40.5
←20
0
SANIBEL—SALINITY
LEGEND
0 – 56 Salinity, parts per thousand, June 3 – 4
0 – 40.5 Sal. ppt., May 28 – 29
Road
Streams and canals
N
0 1000 2000 3000
SCALE IN FEET

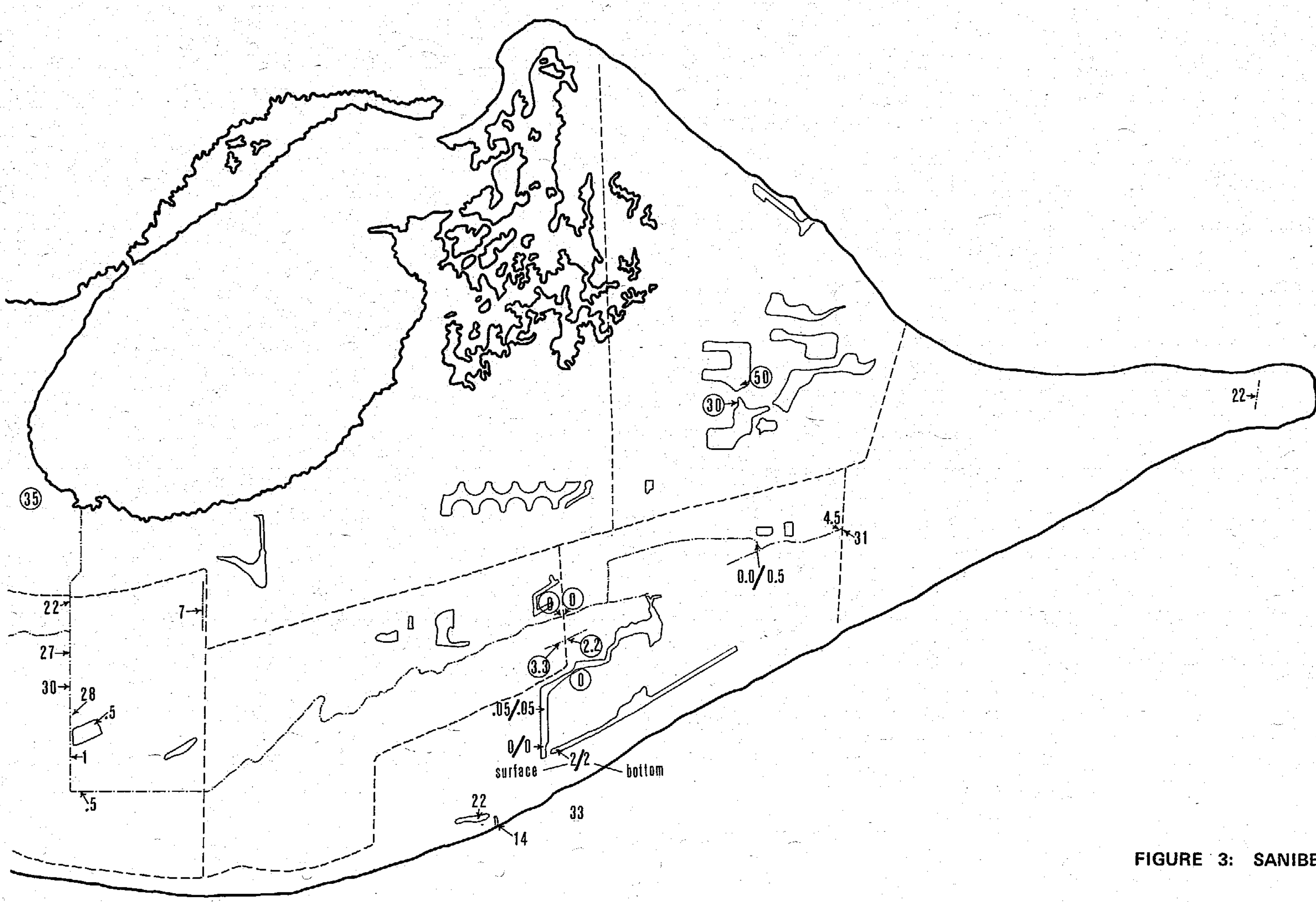

FIGURE 3: SANIBEL - SALINITY

ment tract, in the ditch along Tarpon Bay Road between the bay and the Post Office and moving flood tide water in the Tarpon Bay Canal to within feet of the second set of culverts near Island Road. There was some evidence, discussed in the section on upland vegetation, that salt intrusion was widespread around the same perimeter with effects being most noticeable between SR-867 and the edge of the mangrove forest. Tidal effect on lake levels was noted in the development borrow pit paralleling Gulf Beach Drive.

This brings us to the probable past as well as present condition of aquatic resources, and the water itself, of the interior lowlands. We have only a few studies to guide us to past conditions on this subject, and only one by Schreiner[23] which has attempted to treat the subject of water quality from the habitat suitability viewpoint.

He describes the essential water quality and biotic condition of the Sanibel River and his comments (pp. 7-8) regarding the low bottom oxygen content, virtual absence of benthic organisms other than the larvae of Chironomid midges, and high levels of hydrogen sulfide were supported by our own much more superficial examination. It cannot be doubted that the present channel is acting as a sump for the accumulation of organic material of natural and man-made origin. His description of the presence of coliforms and high nutrient levels added to the conditions of oxygen, benthos, etc., suggests that the channel of the river is in an advanced state of overenrichment and is a poor-to-bad habitat for aquatic organisms. The problem may be further complicated by salt intrusion in the manner discussed in the section on marl soils as well as hastening a changeover in the river from a green algal community to a blue-green system which is notoriously effective under anaerobic polluted conditions. Other problems with the river have been outlined and discussed at length.[26]

Our main attention was directed, therefore, to the ridge and swale topography of the interior lowlands and what the conditions must have been which formed them. Once again, the marl of Sanibel becomes important as we read comments ments such as the following from p. 146:

> ". . . The periphtyon (marl-producing algal community) probably functions as a significant primary producer and an integral part of the food chain . . . Periphyton in other areas has been found to be a food source for mayflies, caddisflies, stoneflies, snails, scuds, zooplankton, and fish."

Continuing to p. 150 we read:

> "Calcareous periphyton develops on plants growing in a variable depth of water though generally the best development of the algae in the upper two feet of the water column."

On the same page Gleason and Spackman[28] comment on optimal conditions for the marl-forming periphyton community.

> "In general the periphyton prefers well-lighted open-spaced communities of barely emergent or submerged plants."

Pondering all the clues available, including the presumed character of pre-development vegetation and rather limited thickness of marl when compared with mainland locations we have come to two possibilities as to the pre-drainage character of island lowlands: (1) the hydroperiod was too short (e.g. August-December) in most years to permit optimum periphyton-marl development, or (2) that the hydroperiod was longer and flooding deep enough to inhibit maximum development. We are inclined to the latter view because of observations made on a large, undrained island south of Naples, Florida. In that location there are ponds which must be very similar, though much smaller, to the swales of pre-development Sanibel. Those ponds have an average maximum depth of about 24 inches during the peak rainy season months of August and September. They dry during severe drought but their bottom muds, which are composed of marl over quartz sand, seem never to dry out. The dominant large plant is <u>Spartina bakeri</u> which, under those conditions, forms spectacular free-standing tussocks in the seasonally flooded centers of the ponds and a dense wall of plants at the pond edges. When the ponds dry, the wet marl bottom sediments are quickly carpeted by <u>Bacopa monnieri</u> and a small needlerush, <u>Eleocharis</u> sp.

During the early rainy season months while water levels are still low and fluctuating, such ponds are "alive" with mosquito larvae, water boatman and, along their sandy margins, fly (Tabanidae) larvae. According to personal observation by Fort Myers Beach mosquito control staff, the mosquito larvae form dense aggregations in these clear waters which can be seen from a low-flying helicopter. There are practically no fish predators in such ponds until later in the summer when water levels have risen high enough to form shallow, overland connection between these temporary ponds and permanent water where residual populations of mosquito-eating fish have survived the winter dry-down.

Ditching has been used to allow ingress of such fish to the insect food can result in equally imagined, free access by fishes to such enormous reservoirs of insect food can result in equally large populations of young fishes by late summer. The difficult part of such management is to prevent over-drainage, for with over-drainage goes much of the natural food production potential of such marshes and a food-chain reaction which culminates in reduction in food supplies for some piscivorous birds.

From these observations, we would surmise that the swales in systems 2, 3, and 4 of the Sanibel lowlands were, with minor differences due to depth potential, virtually identical to the abovementioned ponds. If this is true, the interior of Sanibel was almost certainly a wetland whose swales contained active marl-forming periphyton during the months of May, June, and July. By August, waters would have risen to depths of perhaps two feet at which time Spartina bakerii would be virtually the only emergent plant visible in the swales and around their margins.

Such ponds capture and hold water with the first rains, the depth increase being related to intensity and frequency of such rains. On the basis of limited observations we estimate that these ponds have water depths of a foot or less during May, June and July and the water is very clear. Bacopa and needlerush can be clearly seen flourishing on the bottom during that early rainy season ponding. It is probably during these early rainy season months, while water levels are low and variable, and water extremely clear, that marl formation takes place. With the onset of heavy rains in August the ponds rise to the maximum and their waters darken with tannins from adjacent uplands. The lower light levels, thus available to the benthic periphyton community as a result of increased depth and turbidity, tend to favor non-marl-forming filamentous green algae species. Examination of the fine structure of the marl might confirm this reconstruction of events.

At slightly higher elevations leatherfern would have probably dominated just as they do now, but there would have been no exotic plants and cabbage palms and large buttonwoods would have dominated the higher ridges.

There would have been large populations of killifish but very few sunfishes due to a general absence of deep, permanent fresh-water bodies now provided by lakes, borrow pits and canals.

Water quality in the swales would have been very high, particularly in the more temporary early-season ponds. Dissolved oxygen would have decreased in the deeper water during late summer due to the decomposition of vegetation but probably was not limiting (i.e. below 2 ppm) for benthic organisms.

Nitrogen and phosphorus would probably have been virtually undetectable in water.

Inasmuch as wash-outs of the beach, with resultant overdrainage of the system occurred, there would have been massive drying and oxidation of organic sediments. Salt intrusion probably occurred at such times, at least in the seaward ends of the drained systems. This would have tended to inhibit growth of salt-intolerant woody plant species and gave rise to a community of facultative halophytes.

Inasmuch as the above reconstruction is true, we see a general shortening of the aquatic phase of the hydroperiod, fewer aquatic insects, including mosquitoes, diminished fish population with little change in species composition, and a tendency toward overenrichment of permanent water on the island, and growing dominance of upland plants over original wetland vegetation. Farming, fires, drainage, and pollution have all interacted in various ways to create the present day interior wetland.

Conclusions

(1) From the above description it appears to us that the area south of the Sanibel-Captiva Road between Beach Boulevard and Tahiti Road and north of the beach ridge, can be considered as essentially and originally a freshwater habitat, although it has brackish water characteristics because of saltwater intrusion. Gulf Drive may be considered as the southern extent of land in wetland or contributing to it as recharge area.

(2) In order to keep this wetland area in a natural state, and to maintain the cordgrass habitat, it will be necessary to manage water supplies much more effectively than has been previously the case. It appears to us that in order to manage water, retention of rainfall (the only natural source of freshwater on the island) is absolutely essential. To accomplish this, effective water-level control structures will be needed at Beach Road and also at Sanibel-Captiva Road at the Tarpon Bay structure, and at any other point where the Sanibel River may be connected to saltwater. Other water-management structures would also be desirable at points along the system. All these should be carefully managed and diligently maintained by a responsible city agency having police powers necessary to prosecute violation of the function of the system once installed, in order to prevent the vandalism and sabotage of control structures that has occurred in the past.

(3) Elevation of the hardpan may provide insight into the minimum desired level of the normal dry season water table. Elevation of water in the river has little ecological significance but maintaining dry-season levels at or about the hardpan level would ensure contact between marl bottoms of swales and the water table. This, in turn, would ensure prolongation of the hydroperiod.

(4) As discussed elsewhere in this report, (Taylor Alexander, Section 3) many areas show salt and/or drought effect which only a higher water table would remedy. Maintenance of higher water levels to prevent this stress may require diking and ditching to protect existing development from seasonal flooding.

(5) We have concluded that reconstruction of part of the system would, if possible at all, bring with it larger mosquito populations which would be indicative of a "working" system but which probably would not

be tolerable to the island residents any visitors unless great care is taken in the engineering and management program.

(6) Since the several areas which now receive sewage effluent have eutrophis algal blooms or near bloom conditions, it appears imperative to ensure that non-point sources, as well as point sources, of nutrients be lessened and controlled so as to be of the highest possible quality. To this end retention ponds, sand filters with dry wells and swale should be encouraged wherever possible. Management should plan future development so as to integrate these devices into a system which would keep enriched water in and on the high ground as long as possible. Septic tanks are completely inappropriate for management of sewage in such a system subject to long-term high water table conditions.

(7) In pre-development times there were probably four major natural wetland water "catchment" systems on Sanibel, each with its own intermittent outlet to tidewater. Within each of these systems, which were separated by more-or-less effective major sand ridges at elevations of five or more feet above Mean High Water,there were many low ridges separated from one another by shallow swales. There appear to be about five times as many acres of these low ridges as of swale surface area.

(8) Marl is a constituent of swale bottoms in many areas and is believed to have considerable importance as a "sand sealer" which permits rapid, shallow flooding of a temporary nature during the first three months of the rainy season.

(9) Marl-forming periphyton is productive during those months of shallow and fluctuating depths in the swales.

(10) Those same months were the insect-dominated months; reduction of their numbers by predators began naturally in August as water levels rose to cover the intervening ridges and allowed the fishes to move overland.

(11) The dominant aquatic organisms were those adapted to extremes of light, temperature, salt, and biochemical change. Thus aquatic insects, aquatic larvae of other insects, such as mosquitoes, killifish, and a few tolerant freshwater species, such as the spotted gar.

(12) Drainage has been fairly effective in reducing the swale areas as intermittent ponds but has probably resulted in smaller populations of insect-eating fishes as well as reducing mosquito populations.

(13) Pre-drainage water quality was probably high with nutrients virtually undetectable in water.

(14) Occasional over-drainage of the systems by wash-outs of the beach ridge probably permitted rapid oxidation of accumulated organics which, in turn, reduced the oxygen demand during succeeding impoundment.

(15) Creation of deep canals has permitted accumulation of anaerobic sediments from natural as well as man-made sources with resultant reduction of populations of desirable fishes and invertebrates.

(16) Freshwater fishes, such as sunfish and bass, are now found only in newer ponds or in stretches of the Sanibel River farthest from development because of pollution.

(17) The Tarpon Bay Canal is discharging large quantities of fresh water into a system which had no such discharge prior to development. This water and resultant scouring capability might be put to use flushing east-end development canals.

(18) The interior of the island once had a significantly greater freshwater-storage capacity than now but was subject to loss of that water by beach wash-outs. The frequency of these wash-outs is not known.

(19) If only one or two of the three major storage systems experienced wash-out at any particular time the storage in the others would have acted as a buffer against overdrainage. Combining these systems and preventing maximum storage reduced this buffering potential.

(20) The development of the island has resulted in lower high-water stages and, ideally, prevented overdrainage through wash-outs.

(21) The marl soil found in swales which permits early rainy season ponding leading to a wetland hydroperiod for plants can be rendered ineffective by canals cut across the swales and thus lead to invasion by upland plants which are more successful than the native species.

Upland Communities and Vegetation Management

The upland and wetland vegetation of Sanibel is largely secondary or highly disturbed with the exception of the mangrove community (Section 1). The ecosystem is seriously impacted by exotic plants throughout, with the exception of the tidewater mangroves. The island vegetation at the turn of the century was probably that of an extensive prairie, very much like that of northwest Cape Sable today. Here one sees an extensive graminoid cover with lines of cabbage palm on the slight ridges. Cabbage palms were probably the dominant non-graminoid on all the ridges except the beach on Sanibel.

After abandonment of farming, the first species to invade were the same pioneers one sees today in newly disturbed sites. Wax myrtle, saltbush, and *Iva*, all now dying out under the canopy of taller species, were common invaders. Cabbage palms also underwent a population explosion. The great change came with the population explosion of the two common exotics, Australian pine and Brazilian pepper. Brazilian pepper is the pressing problem in the interior lands. Success over the native vegetation is definitely related to increased activity by man, including fires -- wildfire at first to open the canopy for invasion, and fire suppression later that allowed the invaders to survive until large enough to be fire-resistant.

In terms of impacted land and vegetation, the farmed land represents the area where development would cause the least additional impact on the remnant of the original ecosystem. To return to and maintain original habitat locally will require considerable effort and continuing management. In fact, the Sanibel Island people know today is what it has always been in the eyes of many; and it may only be practical to try to restore limited parts of the ecosystem to the pre-development state. If this decision is made, these areas should be selected with great care.

The following discussion represents ideas and recommendations that are considered to be important to the future ecological situation and habitat management on Sanibel.

EXISTING CONDITIONS

Lemon[36] discusses principal terrestrial communities. His treatment of plant communities is also still essentially valid. However, the community designated "grassland and savannah communities" has parently undergone great changes in the last 20 years. It has been shrub-invaded and some has been lost to development. The only remnants found can no longer be identified as he described the community. Also his "spartina marsh community" is so heavily shrub-invaded by Brazilian pepper, wax myrtle, and saltbush that it no longer looks as he described it, except for very localized areas. This change is considered to have been accelerated by drainage and the control of wildfire in recent decades. His comments on "disburbed areas" have not proved valid in all locations. This is due to the unexpected invasion of many farmed areas by Brazilian pepper and the subsequent domination of the native flora so as to completely modify the order of normal secondary succession for the region.

Under the community identified as "the mixed subtropical forest climax," Lemon suggests sites with "dominants to be Sabal palmetto, Quercus virginiana, and perhaps Pinus elliottii var. densa." And then states "There is a good deal of concrete evidence of this type of community on Sanibel Island." Cooley[13] lists P. elliottii as infrequent in his mixed woods habitat. The writer also found saw palmetto, Serenoa repens, and other pine land dominants at site 35, as well as similar locations. Also in the current field work P. elliottii was found at two sites: 4 (near Dunlop Road) and 30. The above evidence, coupled with Roman's 1774 report (in Cooley[13]) of a grove of pine trees, , strongly supports the concept of the previous existence of pine land on the higher elevations. The possibility and desirability of reestablishment of pine land will be discussed later.

EXOTIC PLANTS

This designation refers to species that have been introduced and are therefore not a part of the native flora. In some cases they have become so common they are listed in floras as "naturalized." In sub-tropical Florida there are several species that have proved to be disastrous to the natural ecosystem. On the premise that diversity in habitat and species is necessary for stability and to supply niches for a varied fauna, some exotic plants are a detriment. These are the ones that tend to form pure stands and eventually out-compete native species. There are two of these on Sanibel that are critical and need control now and several others that could easily become critical.

Casuarina equisetifolia, Australian pine, introduced as a street tree about 1920, has now become the canopy dominant over much of the island and is capable of encroachment on every plant community. It has colonized disturbed areas and the beach. Since much of the island has been stressed or disturbed, the potential of spread into the remaining "natural habitats" is immediate. Wildfire, hurricanes, and man's activities can open the way for immediate invasion. This species is an abundant seeder and wind-distributed seeds are always available. It is salt resistant and can survive in all but the most saline habitats. There are probably two other species of Casuarina on the island. One produces seed and the other spreads by root-sprouting. The latter is a slower but extremely potent invader for this reason. Most native plants tend to die out when shaded by Australian pines and cannot reproduce where a thick carpet of "needles" accumulates.

It is recognized that this tree is the shade tree for residents and does supply habitat for some animals. However, it should be studied with the idea of its restriction to certain areas and its removal from "wild areas." It can be controlled by fire and poison. Stump sprouting is common, so cutting in itself is not a permanent control. It is suggested that two species be considered for replacement of Casuarina canopy. These are the native pine (Pinus elliottii, slash pine) and the native southern red cedar (Juniperus silicicola). As stated earlier, the slash pine already grows on the island. The cedar, common on islands a short distance to the north, has been observed by the writer to start from seed naturally under an Austra-pine canopy. This is an exception to the statement made about the inability of native species to become established under the thick duff. It is felt that using the two natives as a long-term replacement of Australian pine is reasonable. (See additional comment below under "storms.")

Schinus terebinthifolius, Brazilian pepper, was a desirable landscape shrub in the mid-1950's and was not recorded in either the Cooley[13] nor Lemon[36] reports, but was discussed with concern by Provost[27] in 1968. Today it is found in every community, and has produced a closed canopy over much of the abandoned farmland in the eastern part, and has become established and locally dominant in the interior wetlands where it is shading out Spartina. Ordinary flooding does not kill established plants. There is no known control for old established plants except removal. Successful removal by blade, without elimination of all native species, was observed in the 80 acres cleared in 1974 by the Island Beach Club. If a Spartina marsh were renovated in this manner, sprouting and seedling Brazilian peppers could possibly be controlled by prescribed burning. In any event, this plant can follow the same disturbances that Australian pine does and produce large seed crops every year. These are mostly bird-distributed. Its total removal is recommended.

Melaleuca quinquenervia (cajeput or punk tree) is a third exotic capable of dominating a natural habitat in the same manner as the previous species. Isolated seed-bearing trees were noted in several locations. Seed supply is always available on the trees and it is estimated about 17,000,000 seeds are present on an average-sized tree. It needs a wet situation for establishment. Should an area be disturbed and seeds released at a time of favorable soil moisture, a closed community of cajeput would develop. Seed-bearing speciments of this species were noted in several sites. Cajeput is salt tolerant and can invade mangrove communities on the brackish water margins just as Brazilian pepper does. Furthermore, it is not controllable by fire. These trees should be removed and probably some control should be established over their use as landscape trees.

Other exotic species found and considered as possible future problem plants are:

- Psidium guajava - guava
- Sansevieria thyrsiflora - bow-string hemp
- Bryophyllum pinnatum - life plant
- Vitex trifolia
- Wedelia trilobata

FIRE

Use of fire to maintain the Spartina marsh should be considered. Presently, this marsh is being invaded by several shrubs as stated earlier. Dead and dying culms are common under the woody plant margins. The Spartina and associated graminoids would benefit from a properly managed burn. It is most likely that the original extent of Spartina in the internal marsh was related to the wildfires known to have swept the island during the farming period. If a pineland area is established, it too will need prescribed burning to properly maintain it as a community type.

SOIL SALINITY

A few conductivity measurements were made to determine the reason for certain stress symptoms seen on some plants. Most all the samples taken in low areas showed soil salt content too high (above 4 millimhos) to allow crop farming today. Several of the samples were taken where old crop rows were still visible. It is felt that the brackish soil situation has become critical for some of the native species. This stress is aggravated by drought, drainage, and the recent rise in sea level. (See Table of Soil Salinity.)

ENDANGERED COMMUNITIES

The communities that appear critical in terms of survival at this point in time are those designated by Cooley[13] and Lemon[36] as grassland types. These were probably never extensive in recent times and have been encroached by introduced and exotic shrubs as well as used for development. They are mostly associated with the south side of the Island and appear to be characterized today by the occurrence of Dodonea viscosa (varnish lead) in the grassland on the highest locations and by Muhlenbergia cappillaris (muhly grass) on lower locations. These are good rabbit, gopher turtle, and certain bird habitats. Here

TABLE OF SOIL SALINITY

Conductivity in millimhos/cm/25°C

Site 50	1.0 - old citrus, unstressed buttonwoods
Wulfert buttonwoods	2.8 - drought stressed buttonwoods
Bailey tower (site 60)	4.3 - marl slough, stressed plants
Site 49	7.0 - stressed buttonwoods
Marsh, south of river, mid-island	25.0 - killed camphor weed

Crop plant* response related to conductivity

0-2	Salinity effects mostly negligible
2-4	Yields of very sensitive crops may be restricted
4-8	Yields of many crops restricted
8-16	Only tolerant crops yield satisfactorily
16	Only a few very tolerant crops yield satisfactorily

*Tolerances for native species under consideration on Sanibel are not accurately known. However, stress will occur in lowest soils during droughts. Higher soil, given a good water supply, should support most plants except where salt spray is a factor.

again the exclusion of fire has probably been a factor in the dominant species shift.

Spartina marshes are being invaded by saltbush, Brazilian pepper, leather fern, and climbing hempweed. The extent of invasion varies with location. In every case, as soon as shading occurs, Spartina will die out.

BEACH

Much of the beach (not all was visited) appears to lack a good cover of native beach and dune species. Australian pine is frequently tee dominant. In any event, a beach well protected by a cover of native species is the best protection against storm erosion. Sea oats should be planted extensively. Consideration should be given for planting Ambrosia hispida, coastal ragweed, landward of the sea oat zone. It is a common native on many of the coastal islands of the west coast and is an excellent sand binder. Excessive tracking was observed in several sites. This kills vegetation and invites erosion.

STORMS

The Australian pine and the cajeput represent a severe secondary storm hazard. Not only do toppled trees block roads and damage buildings, they also create a peculiar condition in the "wild lands." First there is the accumulation of fallen timber that tends to be caught shy of the ground where it does not rot readily. Of greater ecological concern is the pock-marked effect it produces on the surface. This unevenness is not natural and does affect the distribution of recovery vegetation. The Australian pine forest across the street from the Conservation Office is a good example of this problem. It should also be noted that Fort Myers has a ban on planting these as street trees. This ban was a result of storm-related tree damage. This is further argument for the control of exotic species.

PLANT PESTS

Toxicodendron radicans (poison ivy) has long been recognized as a problem on the Island. It is present in all habitats except the tide-water mangroves. This plant should be controlled in all areas where the public use is high.

PINELAND

As mentioned earlier, Pinus elliottii (slash pine) is present on the island and probably represents a relic community. It is suggested that this tree be introduced to those locations where saw palmetto occurs in the understory. On naturally high land it will also be useful as a yard tree. This plant requires special handling and the State Foresters should be involved for plant source and timing. Once a few trees are established, natural seeding should occur.

ENDANGERED SPECIES

After carefully studying our 61 sites throughout the island, it was felt that endangered species is not presently a significant issue. However, note should be made of the previous comments on endangered communities.

USEFUL NATIVE SPECIES FOR LANDSCAPING

Several species seen during the field work can be useful as landscape plants. A number of these, such as seagrape and cabbage palm, are recognized and are in the trade. It is suggested that the following be considered (there are others, such as the several species of Cacti) and possibly an island nursery be established for a supply.

1. Maytenus phyllanthoides - molina. Small shrub, salt resistant, will grow in mangrove fringes, red fruit.

2. Dalbergia ecastophyllum- legume vine. Excellent to bind beach sand, large woody rambling vine, salt resistant.

3. Jacquinia keyensis - joewood. Excellent small dense foliaged tree, salt resistant.

4. Chrysobalanus icaco - coco-plum. Good hedge plant, responds well to pruning, not salt resistant.

5. Spartina bakerii - cordgrass. Interesting when isolated as a large clump. Good color variation. Fresh and brackish areas.

6. Piscidia piscipula - fish poison tree. Does well in island habitats, leafless in winter.

7. Mastichodendron foetidissimum - mastic. Good-sized tree, good fruit for birds.

8. Ipomoea pes-caprae - railroad vine. Good beach binder and ground cover in area subjected to salt spray.

9. Caesalpinia crista - gray nicker bean. Thorny vine, ornamental and useful to produce barriers, e.g. beach approaches.

10. Pinus elliottii - slash pine. Good evergreen tree, storm resistant, good bird food.

WETLAND SPECIES

The following list comprises the wetland plant indicators common to Sanibel Island. Group I are considered as freshwater indicators, but they may be found in brackish water areas. Group II are indicators of wet areas but are transitional with upland communities. They often form the upper boundary between true wetlands and upland areas. Group III are indicators of marine and estuarine wetlands.

Group I:

Spartina bakerii, cordgrass

Cladium jamaicense, sawgrass

Typha spp., cattail

Bacopa monnieri, water hyssup

Pluchea purpurascens, camphor weed

Sesuvium maritima, sea purslane

Salix caroliniana, willow (only fresh water)

Group II:

Conocarpus erectus, buttonwood

Borrichia frutescens, sea oxeye

Acrostichum danaeaefolium, leather fern

Iva imbricata, marsh elder

Group III:

Rhizophora mangle, red mangrove

Avicennia germinans, black mangrove

Laguncularia racemosa, white mangrove

Salicornia virginica, glasswort

Batis maritima, saltwort

Distichilis spicata, saltgrass

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Recommendations

1. The vegetative communities of Sanibel Island have been severely impacted during the past 70 years or so. It will probably be practical to try to restore only limited parts of the system to the pre-development state. Such areas should be selected with great care.

2. All remaining tidal mangrove communities should be preserved.

3. The mangrove communities to the east of Wulfert Road are effective contributors to the resource base of Pine Island Sound. Their preservation is strongly recommended.

4. The fringes of tidal mangroves, predominantly red mangroves, bordering Dinken Bayou, Old Blind Pass, and Blind Pass should be preserved. The buttonwood-black-white mangrove complex landward of these may be considered expendable.

5. A planting program should be initiated to establish a cover of sea oats and coastal ragweed on the beach dunes, which were devoid of good stabilizing ground cover at most of the sites visited.

6. Serious consideration should be given to leveling the bottom of the Sanibel River and tributaries to eliminate sediment traps and inhibit development of anaerobic conditions.

7. If cost and engineering considerations permit, thought should be given to setting aside some additional portions of catchment areas 2, 3, and 4 for restoration and management at higher water levels, and to diverting surplus from these areas east via the "leveled" river to the outlet at Beach Road where such flow might move canal organic sediments seaward. If this is a reasonable alternative to Tarpon Bay discharge then a sand-trap lake should be placed at some point upstream of the Beach Road structure to prevent siltation of receiving waters at Lingren Road.

8. Since nutrients were almost certainly limited to undetectable levels in pre-development waters, sewage effluent from any source should be kept from interior wetland areas. To this end, consideration of an easterly flowing runoff pattern be-

comes even more critical and areas within the present development zone more important for land disposal.

9. Wherever canals exist, all unnatural (i.e. exotic) vegetation which contributes debris to the water should be removed, by hand if necessary. This applies especially to Brazilian pepper and Australian pines.

10. Control of Casuarina by fire and poisoning is recommended in "wild areas." Pinus elliottii and Juniperus silicicola (southern red cedar) should be considered for use as replacement trees. Similarly, Brazilian pepper and cajeput should be removed from the island by a continual cutting program.

11. Spartina and associated graminoid communities would probably benefit from a program of controlled burning to remove invading shrubs.

12. Additional culverts should be installed beneath the "Darling Memorial Drive" to increase tidal influence within the artificial impoundment. (We do not recommend the diversion of fresh water into the impoundment.)

13. Any decision concerning the installation of further culverts beneath Dixie Beach Boulevard should be delayed until the character of the redeveloping mangrove community to the east becomes discernible.

14. No runoff from any adjacent urban development projects should be directed into the heads of Dinken Bayou or Old Blind Pass. Tidal flushing is probably inadequate to prevent accumulation of dissolved nutrients and particulate organics. The tidal mangrove fringe is insufficiently large to be a significant nutrient scrubber.

APPENDIX 3

APPENDIX 3

BEACH GEOLOGY

by Stanley R. Riggs

"If man wishes to build his works on the fringes of such a battleground (the coast), he must understand that the rules of this ancient battle require the beach, the berm, and the dunes to shift constantly before the assault of the sea."

C.J. Schuberth, 1971

The coastal zone is probably the most dynamic natural system on the surface of the earth. The continuously operating processes of the waves, tides, and currents, along with the all-too-frequent high energy storms, are continuously affecting and modifying this buffer zone between the ocean and the land. Sanibel, like any coastal zone, is both a consequence of its geologic past and a product of the dynamic geologic processes operating daily and continuously. There is now another major variable which will dictate to a large extent the future responses of the coastal zone -- man. The construction of extensive walls of condominiums, summer homes, resorts, and highways along the beach areas produces "permanent" economic barriers within a highly dynamic, changeable natural system. Thus, we take a not-so-fragile natural system that gives with and modifies itself to the ever-changing energy regimes and processes of the coast, and produce a "quasi-permanent" system that is no longer allowed to change. Thus, we create a very "fragile" system that is in an increasingly more stressed equilibrium situation. This stressed system will exist, however, only until it is subjected to major periods of high energy. At this time major change will occur and the "fragile" system will ultimately be restored to a natural equilibrium, but now at man's expense.

"Protection of our seacoasts" has been a priority project throughout the twentieth century. This attitude evolved with the development of our life-style which includes second homes and leisure living along with the development of major industries in tourism, recreation, and water-based sports. The attitude of man combating nature to control all potentially destructive natural coastal processes has been at the center of the U.S. Army Corps of Engineers' efforts to develop methods and implement coastal protection along the shorelines throughout our country. The Corps' philosophy is dramatically stated in their publication entitled Land Against the Sea (1964) in which they conclude the report with the statement "Our campaign against the encroachment of the sea must be waged with the same care that we would take against any other enemy threatening our boundaries." (p. 43) Largely because of this philosophy, we have approached open defiance and challenge. This all-pervasive "man against the sea" philosophy has not only been totally unsuccessful, but all too often has culminated in increased adverse coastal responses. Schuberth (1971) states that "if man tries to change these rules (of the natural beach), he can only fail; and in his failure he may even undermine the fragile hold of these outposts against the powerful sea." Our present attitude towards the use and "protection" of the coastal area does modify the coastal environment; the form and magnitude of the modification varies with the activity and the environmental sensitivity. These modifications stress a delicately balanced natural system, generally disrupting whatever equilibrium does exist and thus accentuates the problem and compounds the consequences.

Minimal detailed geological or engineering data are available for the Sanibel Island area. The relatively few studies which have been done are good, however very limited. Even though I do not necessarily agree with the conclusions of this work, my intent is to use the data as a basis upon which to question and challenge the classic approach of resolving the conflict of "man against nature" within the Sanibel coastal zone. I believe we can no longer afford to attack nature as a bad guy that needs taming, controlling, and molding into our ideas of the "way it should be." We have lost in most of our efforts with this classic money-driven approach in attempting to derive total economic development potential out of the coastal zone. The basic environmental losses, as well as the long range economic costs and losses to man are incredible. We must start working with "the proposition that nature is process, that it is interacting, that it responds to laws, representing values and opportunities for human use with certain limitations and even prohibitions to certain of these...we must realize man's design with nature" (McHarg, 1969).

Sanibel Island became incorporated as a city with a preamble that reads "...an island community known far and wide for its unique atmosphere and unusual natural environment, and to insure compliance with such planning so that these unique and natural characteristics of the island shall be preserved." Through home rule, the great majority of citizens decided to guarantee the preservation of the "natural systems" which are not only the basis of their economy but which also make Sanibel Island unique among coastal islands. The enclosed technical report on the beach system of Sanibel Island provides a set of recommendations based upon the specifications as defined by the natural system itself. These are the requirements that are dictated by the natural processes and are essential if the coastal system is going to be preserved in both a healthy and stable non-stressed condition and if development is going to proceed in a fashion to guarantee the greatest safety for life and property.

The Sanibel Island Coastal System

Sanibel Island occurs within an extensive barrier chain which extends from Anclote Key south to Cape Romano along the Gulf of Mexico coast of western peninsular Florida. In the specific area of this study, the Fort Myers area, the barrier chain encloses a large estuarine body dominated by Charlotte Harbor with numerous smaller sounds and bays around the perimeter (Figure 1). The Charlotte Harbor estuarine system is bounded to the east and north by the very low and swampy lowlands of peninsular Florida from which it receives the fresh water discharge through three major rivers: the Myakka, Peace, and Caloosahatchee Rivers. The estuarine system is bounded on the Gulf of Mexico side by five barrier islands, which include Sanibel Island. These islands are separated by five passes which connect the estuarine system with the Gulf of Mexico. Seaward of the barrier islands is the Gulf of Mexico with a very broad shallow continental shelf. The Gulf waters respond quickly to the many frequent fluxes in the basic energy regime of the atmosphere producing complex wave, current, and storm tide systems which are superimposed upon the normal astronomical tidal system. This system of mainland, rivers, estuaries, barrier islands, inlets, and nearshore shelf, along with the respective energy regimes and the resulting processes, represent a total coastal unit. This unit is an integral system of environments and processes in which each part interacts with all other parts; a given process in one part of the system will produce responses in each other portion of the coastal unit. All of the adjacent environments and the basic processes of each portion of the system must be included in developing any management or land use plan. Therefore, I will briefly describe each part of the coastal unit in this section and will get into the pertinent geologic processes and responses as they relate to Sanibel Island in the next section.

BARRIER ISLAND SYSTEM

The estuarine system is bounded on the Gulf side by five barrier islands which extend some 30 miles south from the Charlotte-Lee County boundary to San Carlos Bay (Figure 1). The four northern islands are a relatively narrow and short string of islands which trend north-northwest. The islands range from about 200 feet up to a little more than a mile in width and from 4 to 7 miles in length. Sanibel Island, which forms an arcuate-shaped hook across the southern end of the Charlotte Harbor estuarine system, is considerably larger than all of the other islands. It is about 12 miles long and varies in width from about 1/2 mile in its narrowest zone to almost 2-1/2 miles at its greatest width. Since Sanibel is arcuate-shaped, it actually trends northwest on its western edge and curves around to the northeast on the eastern tip. This produces a generally east-west orientation with a south facing Gulf shoreline which is in great contrast

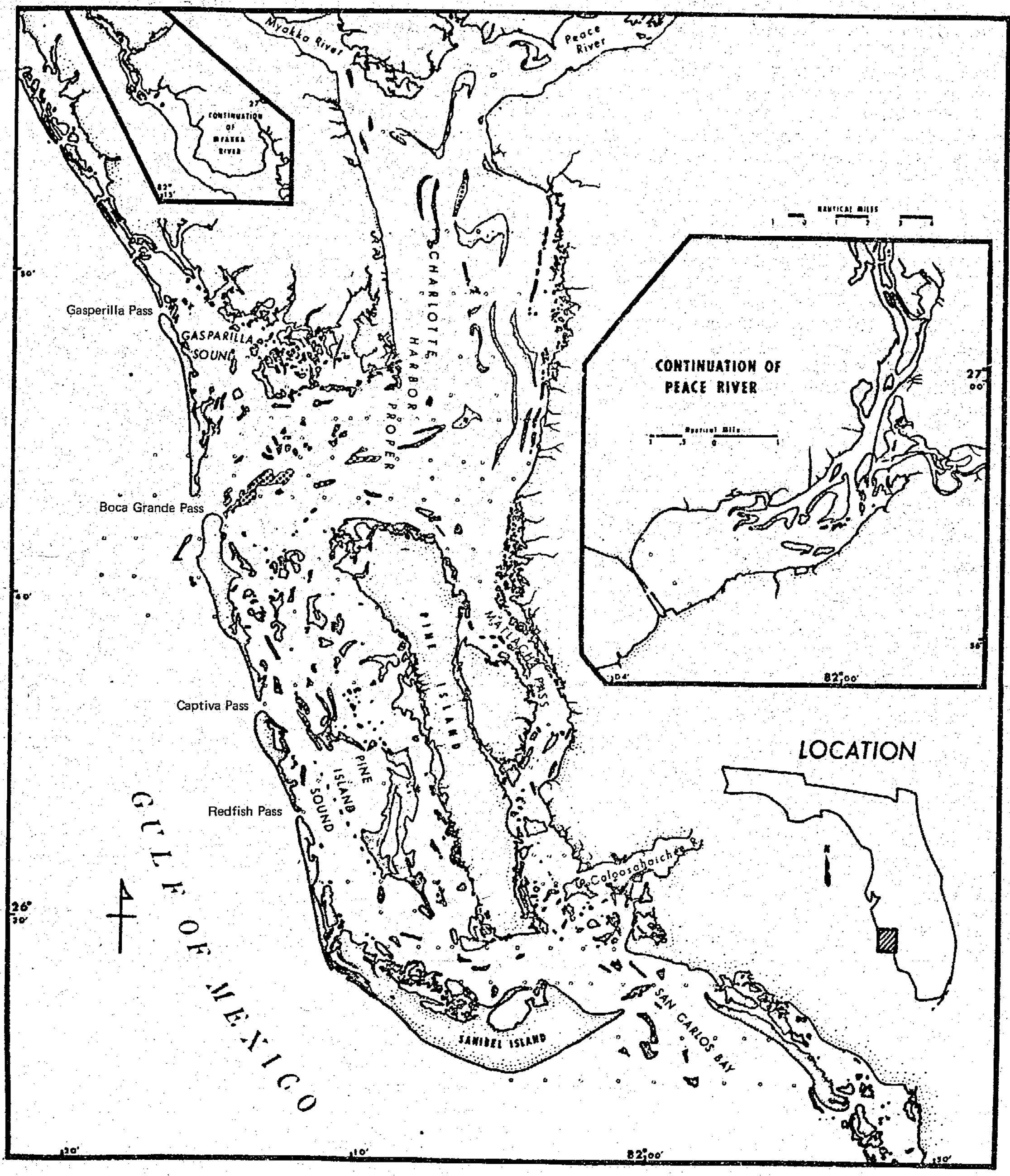


Fig. 1 - Location map of the Sanibel Island coastal system, Florida.

to the east-southeast facing shorelines of the other barrier islands. The major differences in the size and orientation of Sanibel reflects a considerably different set of geologic conditions than are operating on the other barriers. This will be discussed in greater detail later in the paper.

ESTUARINE SYSTEM

The brackish water estuarine system located behind the barrier islands is dominated by Charlotte Harbor, Pine Island Sound, and San Carlos Bay with a multitude of smaller coastal embayments around the perimeters (Figure 1). This estuarine system represents a complex set of drowned river channels, flooded by the rising sea level during the past 10,000 years, the Holocene transgression. These very shallow water bodies range in depth from 0 to 20 feet except in the major channels where water depths range from 10 to 50 feet. The tortuously irregular shorelines consist largely of intertidal mangrove swamps, Spartina marshes, and tidal flats. The brackish waters of the estuaries range from almost fresh well up to the mouths of the three main rivers to almost normal marine around the tidal inlets on the west. The estuarine circulation is controlled by the tidal flow through the inlets and the fresh water discharge from the rivers. The normal volume of the river discharge exceeds the normal tidal influx producing higher ebb current velocities than flood current velocities through the inlets (Huang and Goodell, 1967).

There has been only very minor erosion or deposition within the estuarine system during the past 100 years. The deposition has been in river mouths and the central regions of the sounds while the erosion has occurred within the tidal channels (Huang and Goodell, 1967) and along a few of the more open shorelines. Huang and Goodell describe the sediments within the estuarine system as being dominantly fine quartz sands with abundant, but highly variable, concentrations of carbonate shell hash and some silt and clay. The sediments generally become finer away from the channels and in landward directions. The textural distribution of the sediments generally correlates with the water circulation in the estuarine system. The terrigenous (land derived) sediments are inherited primarily from the erosion of adjacent parent rocks, whereas the bioclastic material is largely indigenous. Huang and Goodell believe that the relatively small amount of silt and clay in the system reflects the lack of a fine-grained parent source.

MAINLAND AND RIVER SYSTEM

The mainland area of peninsular Florida that bounds the estuarine system on the east lies in the geomorphic province of the Coastal Lowlands (Figure 1). The land is extremely low in elevation and is very poorly drained with numerous cypress swamps. The drainage that does exist flows through three major river systems into the Charlotte Harbor estuarine system. The Myakka River, the smallest of the three rivers, drains southward from the nearby coastal lowlands into the northwest corner of Charlotte Harbor. The Peace River, the largest of the three rivers, drains out of Lake Hancock in the phosphate district portion of the Polk Upland and flows into the northeast corner of Charlotte Harbor. The Caloosahatchee River drains almost due west from Lake Okeechobee through the Caloosahatchee Valley and into San Carlos Bay in the southern part of the estuarine system. Since all three of these rivers are black water streams that drain the low and swampy coastal and interior lowlands, the sediment load is extremely low. The sediments that are delivered to the estuarine system are primarily dissolved material with only minor suspended sediment, much of which is high in organic composition. Because of the very low stream gradients and relatively low discharges under normal nonflood flow conditions, brackish water occurs well up the mouths of the rivers due to tidal mixing.

The surface sediments on the land area surrounding the Charlotte Harbor estuarine system are primarily Pleistocene sands, shelly sands, and organic rich sediments. Underlying this layer of surface sediments throughout the area is the Anastasia Formation which is dominantly a coquinoid limestone with some sand and clay (Puri and Vernon, 1964).

INLET SYSTEM

Charlotte Harbor is connected with the Gulf of Mexico by five inlets which separate the barrier islands (Figure 1). These inlets might better be thought of as outlets, since their most essential function and the process that generally will control the magnitude and stability of the openings through the barriers is the removal of the continuous flow of fresh water drainage being discharged off the mainland into the estuary. The two major inlets, or outlets, which are fairly stable, appear to carry the bulk of the fresh river water and marine tidal exchange in and out of Charlotte Harbor. Boca Grande Pass in the north is the primary outlet for the fresh water discharge from the Myakka and Peace Rivers, whereas the very broad San Carlos Bay, on the east side of Sanibel, is the main outlet for the Caloosahatchee River. The two intermediate size passes, Captiva and Redfish, open into Pine Island Sound and appear to be only moderately stable. These two passes occur opposite the very large Pine Island which is in the middle of Pine Island Sound. Consequently, there is no direct major river discharge into this area; thus, these inlets respond primarily to tidal processes. Redfish Pass has been open only since 1926.

The fifth inlet, Blind Pass, also opens into Pine Island Sound and separates Captiva Island to the north from Sanibel to the southeast. It is essentially a tidal inlet since it is farthest from the direct influence of a fresh water river discharge and is consequently the most unstable of the five passes. Blind Pass has a dramatic history of migration and closings and openings in response to storm action. This Pass was closed in 1962 and re-opened in 1972 in response to Hurricane Agnes. It has been open since 1972.

NEARSHORE SHELF SYSTEM

The Florida Platform is an extremely broad, shallow continental shelf system that extends westward approximately 250 km off the coast of peninsular Florida. The outer edge of this platform is marked by the precipitous Florida Escarpment (Figure 2). The nearshore portion of the shelf in front of Sanibel Island is characterized by two general topographic zones. The forebeach, the steepest part of the nearshore shelf, extends from the surf zone down to about the 24-foot contour on the northwest and to about the 18-foot contour on the southeast end of the Island. This active high energy zone extends offshore about one mile. At the base of the forebeach, the slope decreases to about 2 to 3 feet per mile and continues seaward as a relatively flat plain with only minor topographic features. The inner portion of this area is characterized by a strong northwest-southeast ridge and swale topography which has an approximate relief up to 10 feet.

CLIMATIC SYSTEM

According to Jordan (1973), the climatic system of the Gulf of Mexico is characterized by a subtropical high-pressure belt which extends over or near the Gulf throughout the year. From March through September, the atmospheric circulation of the eastern Gulf is characterized by a general clockwise circulation pattern related to the areal position on the western portion of the Bermuda high-pressure cell. From October through February, a western anticyclonic cell separates from the Bermuda high and is nearly stationary over the central Gulf, producing a predominant air flow from northwest to north over the eastern Gulf. Thus, Jordan concludes that in the spring and summer the eastern Gulf is influenced predominantly by tropical air masses arriving from the south and southeast and producing a prevailing southern air flow. Whereas in the late fall and winter, the cold air masses from the continent produce a prevailing northerly air flow which is shown in

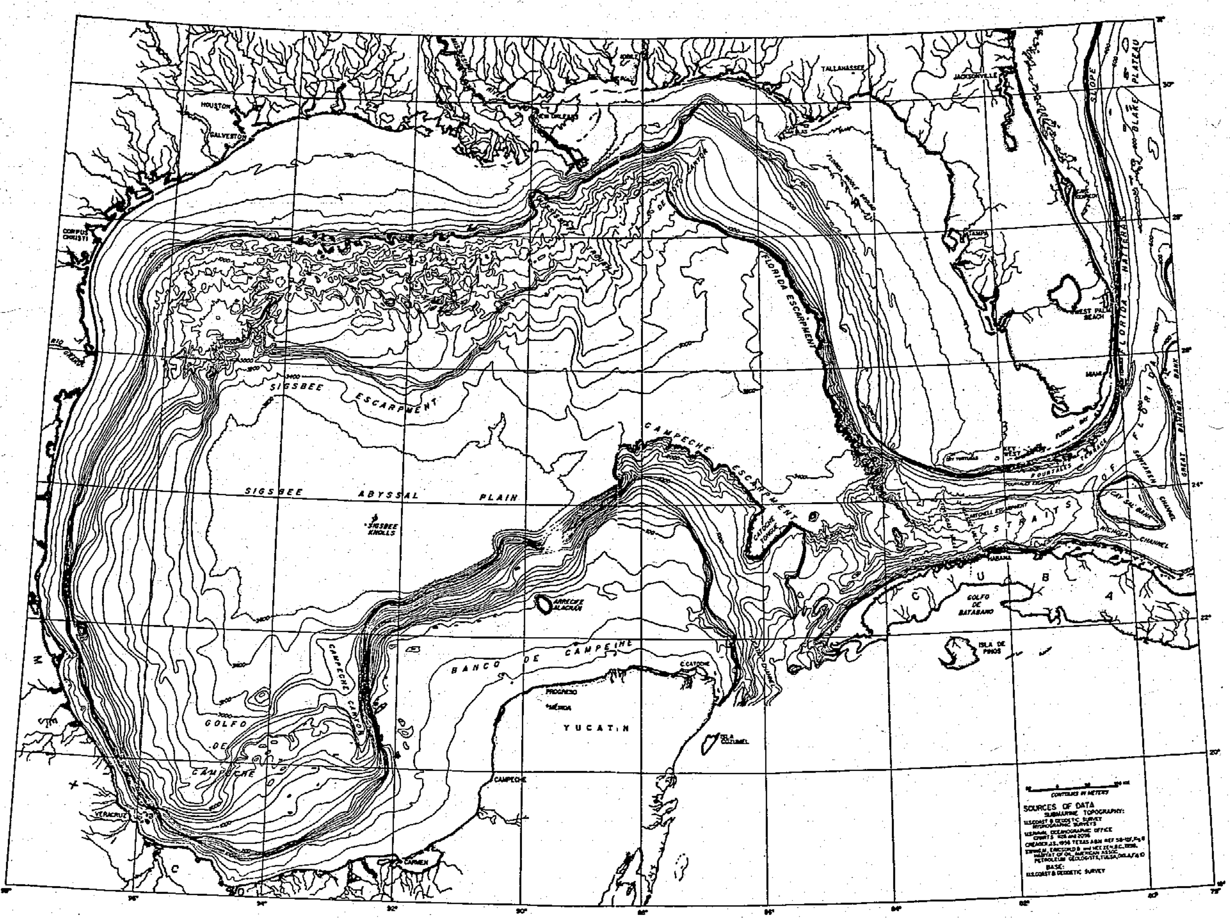


Fig. 2 - General bathymetry of the Gulf of Mexico (From Uchupi and Emery, 1968)

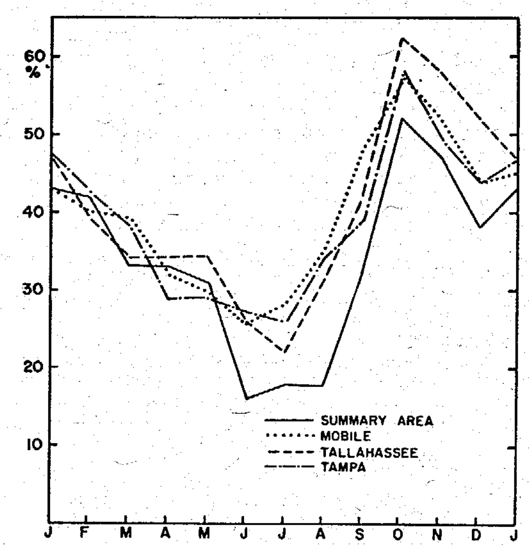


Fig. 3 - Mean percentage of observations with northerly winds, i.e., from northwest, north and northeast, for each month of the year for the stations indicated. (From Jordan, 1973)

Figure 3. Seasonal wind speeds are generally highest during winter and spring and lowest during summer with the exception of local circulations associated with thunderstorms (Figures 4 and 5). Thunderstorms are quite frequent in the eastern Gulf with about two-thirds of them occurring from June through September. This reflects the greater convective activity over the land mass during the summer.

Hurricanes are a definite part of the climatic system of the eastern Gulf. Jordan (1973) states that the probability of a tropical storm or hurricane in the eastern Gulf during any given year is about 50 percent, whereas the probability of two during any given season is about 15 percent. The hurricane season starts in June and extends through November in the southeastern Gulf with very rare occurrences in winter and spring. Figure 6 shows the hurricane tracks in the eastern Gulf during the period 1941-1971 while Figure 7 covers the period from 1830-1966 in the Fort Myers area. Table 1 summarizes some of the hurricane frequency data of Jordan (1973) for the southeast Gulf area; these storms would directly influence the Sanibel Island area to some extent. The U.S. Army Corps of Engineers (1969) states that between 1830 and 1968, 23 hurricanes and 23 tropical disturbances have passed within a 50-mile radius of Lee County. While there have been 17 hurricanes and 14 tropical disturbances between 1900 and 1968, the latter figures represent a relative frequency of one major storm every two years. Most of these hurricanes form in other areas and move into the Sanibel Island area. According to Jordan, the hurricanes in the eastern Gulf will generally arrive from the south during June, whereas the storms in the period from August to September are more likely to come closer to land since they are more likely to be coming from the southeast. Some hurricanes and tropical cyclones do form in the eastern Gulf; 14 such storms formed between 1901 and 1971 (Jordan, 1973).

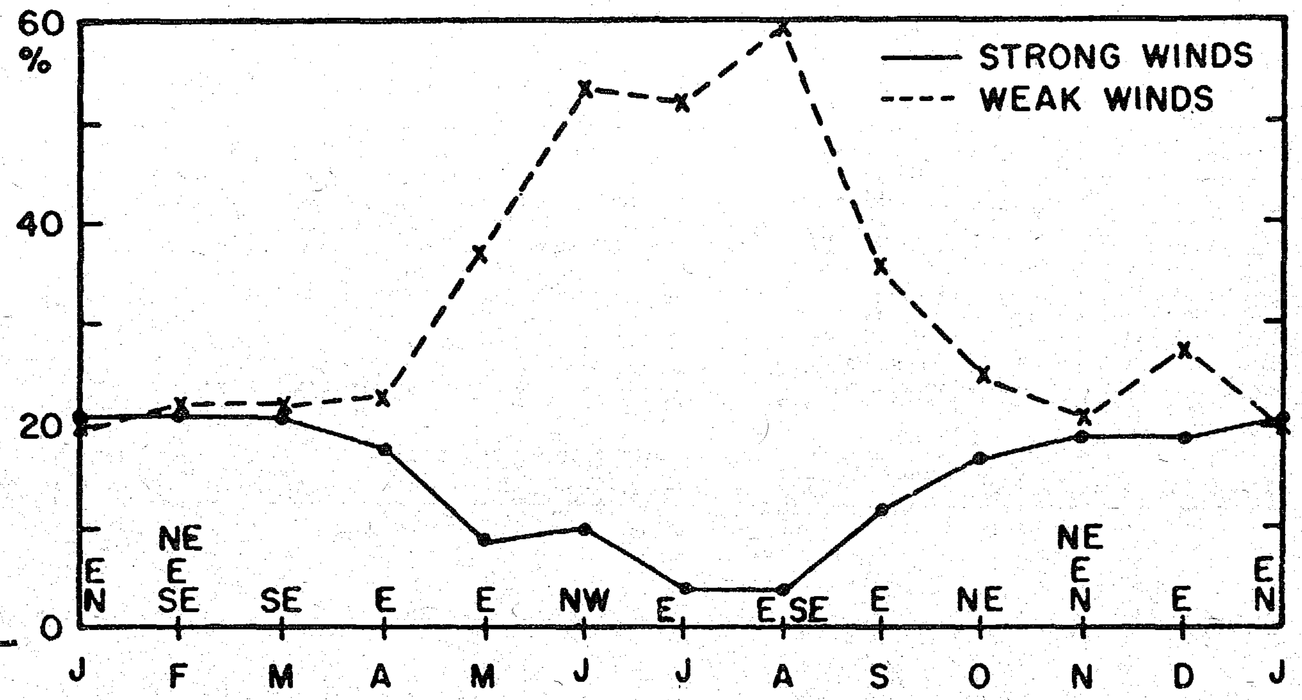


Fig. 5 - Seasonal distribution of frequency (percent) of strong winds (> 17 knots) and of weak winds (< 6 knots) for the summary area. The most frequent direction of the stronger winds is shown for each month at the base of the figure. Multiple directions are shown for some months. (From Jordan, 1973)

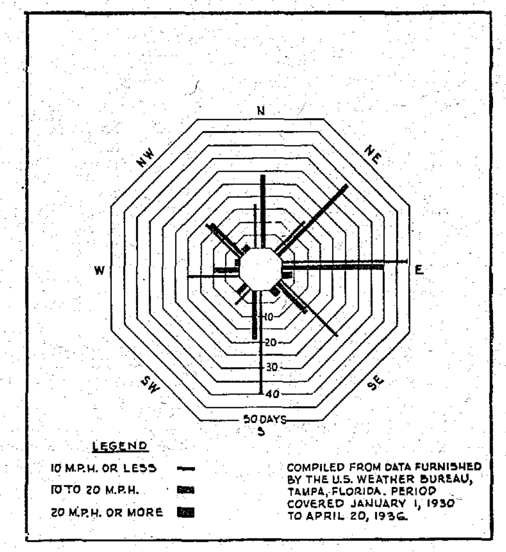


Fig. 4 - Average direction and velocity of winds for one year at Tampa, Florida. (From U.S. Army Corps of Engineers, 1969)

Extratropical cyclones or low-pressure centers which form along slow moving cold fronts are very abundant in the eastern Gulf with an average of 11.1 per year moving inland. The greatest bulk of these occur in the winter with a decreasing frequency in the fall, spring and summer. The extratropical cyclones are most common in the northeast Gulf where they average 9.4 storms per year as compared to the southeastern Gulf where they average 1.7 storms per year (Jordan, 1973).

The wind systems of the Gulf generally respond to the basic seasonal changes in atmospheric circulation patterns and to the storm patterns. Subsequently, the winds and storms affect the wave, swell, storm tide, and current systems of the Gulf as well as the volume and rate of fresh water discharge from land. All of these energy regimes may be affected for days or weeks at a time. It is during these abnormal periods of high-energy influx that most of the geologic work is done. The coastal system has to be able to respond to these high-energy fluxes in order to maintain an equilibrium system.

PHYSICAL OCEANOGRAPHY

Wind conditions in the eastern Gulf suggest that moderate seas exist throughout the area for most of the year. Table 2 summarizes some of the wave data for the eastern Gulf area (Jordan, 1973). According to this data the wave directions tend to be dominantly from the east and northeast from September through February and from the east and southeast from March through August. The waves from the north and northwest tend to have greater wave heights than those from other directions, particularly during the fall and winter, consequently supplying the heaviest seas during these seasons.

Swells are also wind-generated waves but differ from sea waves in that they have long crests, long periods, and low steepness, and have moved out of the influence of the winds which created them. Table 2 summarizes the swell information for the eastern Gulf and Figure 8 depicts the swell information diagramatically for the Gulf off Lee County between 1932 and 1941.

The astronomical tides in the Sanibel area are mixed consisting of diurnal tides during part of each month and semi-diurnal tides during the remainder of the month. The mean tidal range varies from 1.1 feet at Gasparilla Island to 2.0 feet at Little Hickory Island while the mean diurnal range varies from 1.7 feet at Gasparilla Island to 2.9 feet at Little Hickory Island (U.S. Army Corps of Engineers, 1969).

Storm tides are not related to astronomical tides, but rather occur in conjunction with any of the major storm systems previously discussed. Such tides are really wind tides produced by individual storms and have no regularity or predictable height patterns. Storm tides can be extremely high, particularly if superimposed upon normal high astronomical tides, and can be of any duration. The height and duration are directly dependent upon the magnitude, consistency, and duration of the storm winds; this is largely what determines the amount of coastal flooding and resulting damage, as well as the geologic work done within the coastal zone by any given storm. Storm tides up to 12 and 15 feet have been reported in the Sanibel Island and Fort Myers areas (U.S. Army Corps of Engineers, 1969). Major storms that approach the Sanibel area from seaward are capable of producing extreme storm tides because of the very broad shallow continental shelf area.

Very little detailed work has been done on the basic current and circulation patterns of either the

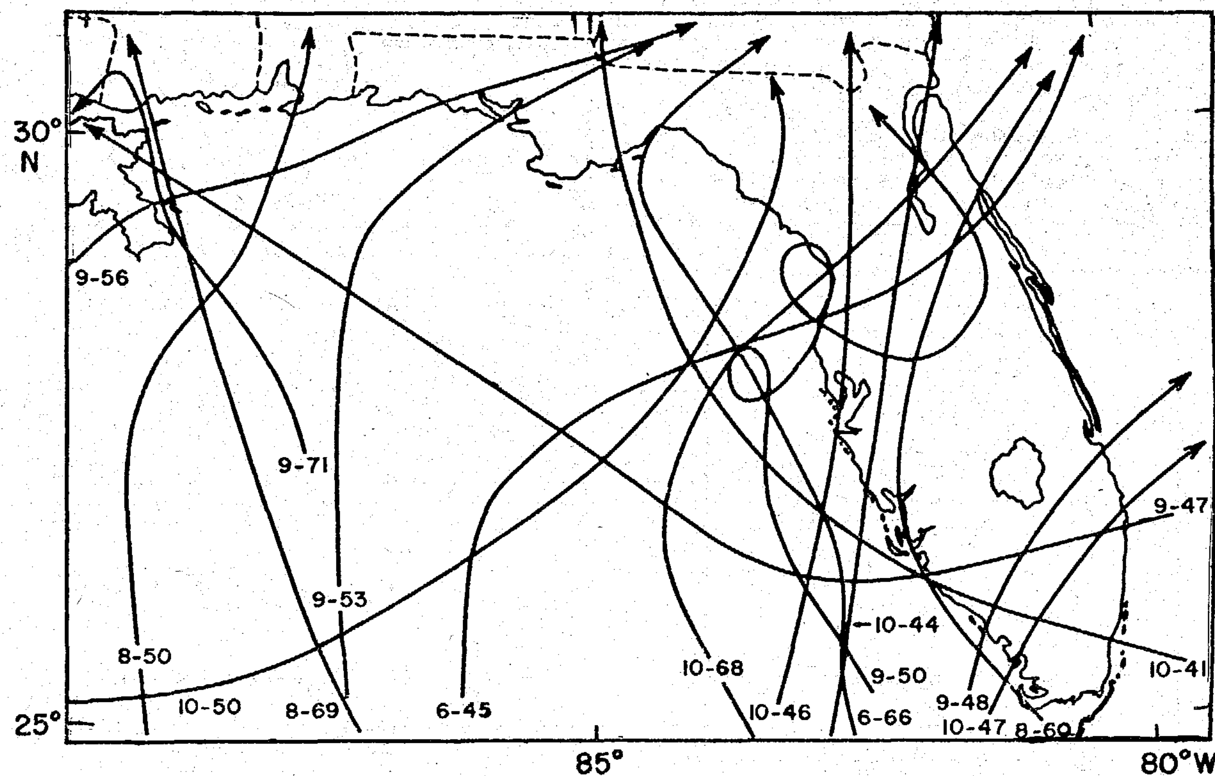


Fig. 6 - Hurricane tracts for the eastern Gulf during the period of 1941-1971. Tracks of storms not attaining hurricane intensity have not been included. Also hurricanes which moved northward over the peninsula of Florida, and which may have influenced the eastern Gulf to some extent, have been omitted. (From Jordan, 1973)

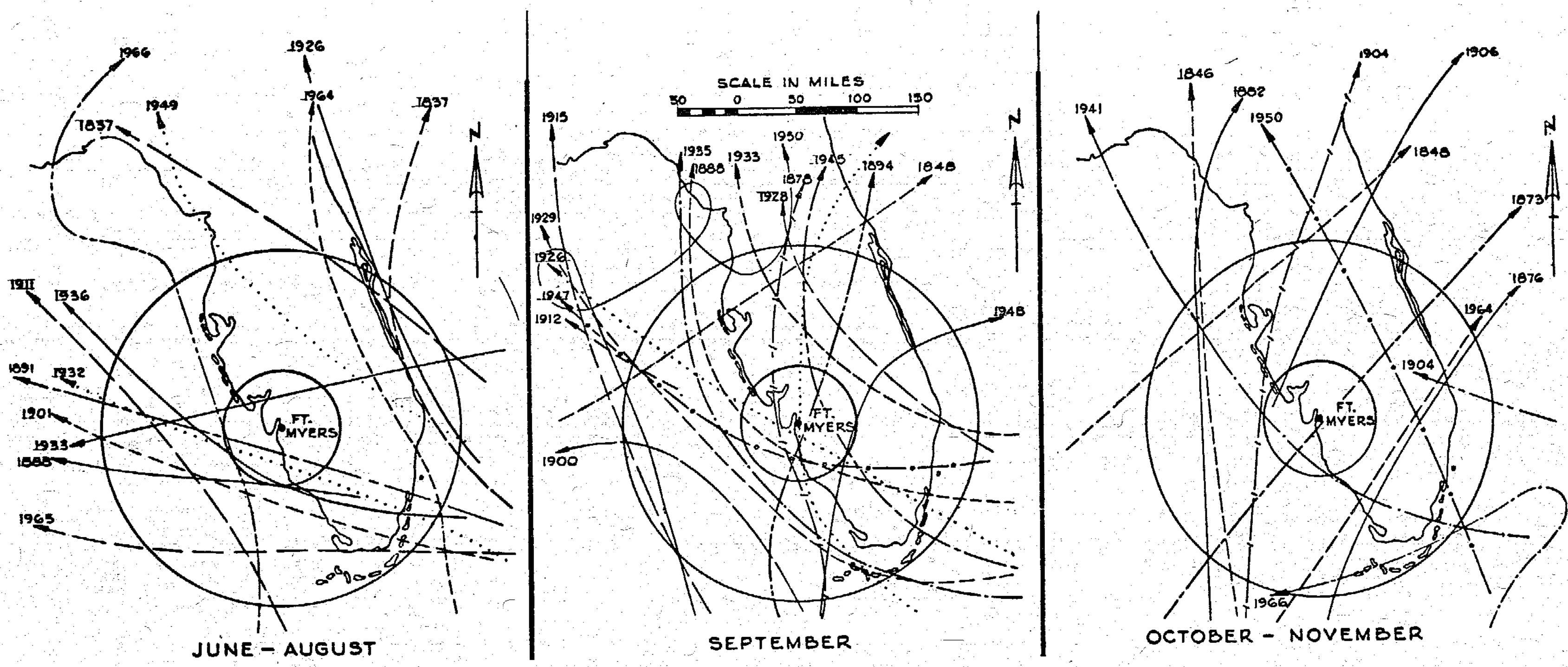


Fig. 7. Paths of tropical storms of hurricane intensity that have passed within approximately 50-mile to 150-mile radii of Lee County, from 1830 to 1966 inclusive. (From U.S. Army Corps of Engineers, 1969)

Florida shelf or of the Sanibel Island area. The published current patterns (Figure 9) indicate a general northward drift on the shelf during most of the year (Jones, et al., 1973). This northward current is produced by eddies in the eastern shelf area which are driven by the major Loop Current which moves clockwise through the central Gulf. This northward drift inside the 10 meter contour in the Tampa-Fort Myers area has recently been confirmed by drift bottle studies (Jones, et al., 1973). The latter study demonstrated that some other feature, in addition to the wind stress, controls the surface circulation within the Tampa-Fort Myers area.

Within the zone of the fore-beach itself, the longshore currents are the primary currents; these are the product of the basic wind patterns and astronomical tides. Most of the limited knowledge of the longshore currents within the Sanibel area is based upon the indirect evidence of sediment movement and wind patterns. The Corps of Engineers and the Coastal and Oceanographic Engineering Laboratories have random measurements of tidal flow in several different inlets made as a result of their many surveys within the area. However, to my knowledge, no one has made detailed, continuous current studies in the nearshore area on a year round or seasonal basis. The dominant prevailing wind direction during the winter is northeast, which would produce a southward longshore current and sediment transport. During the summer, the southwest winds are dominant producing a northerly drift. However, since the stronger climatic pattern is the winter system, it is assumed that the net longshore current system is southerly. This would be greatly modified by individual storms and around inlets where there is a complex influence of the tidal currents.

Geologic Framework of Sanibel

HOLOCENE SEA LEVEL CHANGES

There have been many exhaustive studies of the Pleistocene sea level fluctuations; consequently, there is a pretty good understanding and agreement of the major sea level events (Figure 10). The general character of the most recent transgression, which began about 17,000 B.P., is depicted in Figure 11 and shows the results of numerous studies. The exact times and rates of sea level change within this most recent Holocene transgression, which we are still experiencing, is open to considerable academic discussion. However, there is no question about the present overall trend; this, of course, is a most important point with respect to the present discussion.

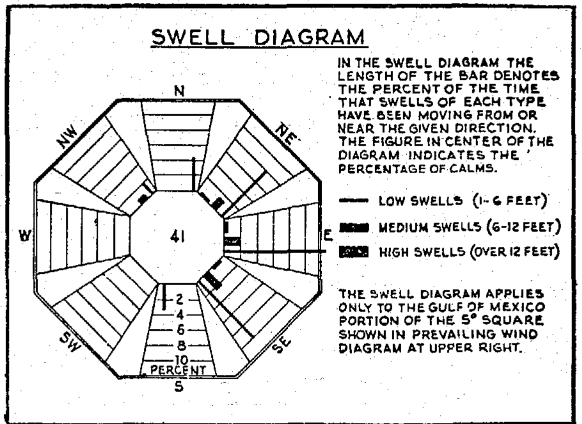


Fig. 8 - Swell diagram of portion of Gulf of Mexico off Florida West Coast. (From U.S. Army Corps of Engineers, 1969)

June	July	August	September	October	November to May	Total
11	4	16	21	25	7	84

Table I - Hurricane and tropical storm frequency in the southeast Gulf area during the 1901-1971 period. (From Jordan, 1973)

Figure 12 shows the recent sea level rise data of Hicks based on N.O.A.A. tide gauge information at Cedar Key, Florida (Brooks, 1973). This data suggests a four-to-six inch rise in the sea since 1910. This is in line with the general 8 to 10 inches of sea level rise during the past 100 years as developed by N.O.A.A. for this area (Brooks, 1973).

The importance of the sea level information to barrier islands and coastal processes has been dramatically pointed out by many geologists including the work of Riggs and O'Connor (1974), O'Connor and Riggs (1974), Brooks (1973), and Bruun (1962) to mention only a few. The level of the sea determines the position of the beach and all associated beach processes with respect to land. If the level of the sea changes with respect to the land, the beach zone will migrate. Bruun (1962) has calculated that on a normal coastline, a sea level rise of one foot may cause a shoreline regression of more than one hundred feet. The rate and degree of shoreline response is largely a function of the rate and magnitude of sea level change and the geomorphology of the associated land areas. Since, in the Sanibel area, the high-energy coastal system is rising across a land area characterized by very low elevations and relief, the rates of land recession (erosion) or beach zone migration will be very great. Several other variables do come into play which may either accentuate or eliminate the consequences of a rising sea level. These include such factors as the tectonic stability of the area; "new" sediment supply; orientation and geographic location of the specific coastal system with respect to

	WAVE HEIGHT	
	October - April	May - August
<3 feet	60-65% of observations	80-90% of observations
>5 feet	10-15% of observations	2-6% of observations
>12 feet	1% of observations	<1% of observations
	WAVE PERIOD	
	All Seasons	
>5 seconds	61-74% of observations with the greatest frequency during the summer and the lowest frequency during the fall	
<9 seconds	5-6% of observations	
	SWELL	
	September - April	May - October
<6 feet	72-80% of observations	86-93% of observations
>12 feet	3-6% of observations	<2% of observations

Table 2 - Wave data for the eastern Gulf of Mexico (From Jordan, 1973 and based upon the U.S. Naval Oceanographic Atlas, 1973)

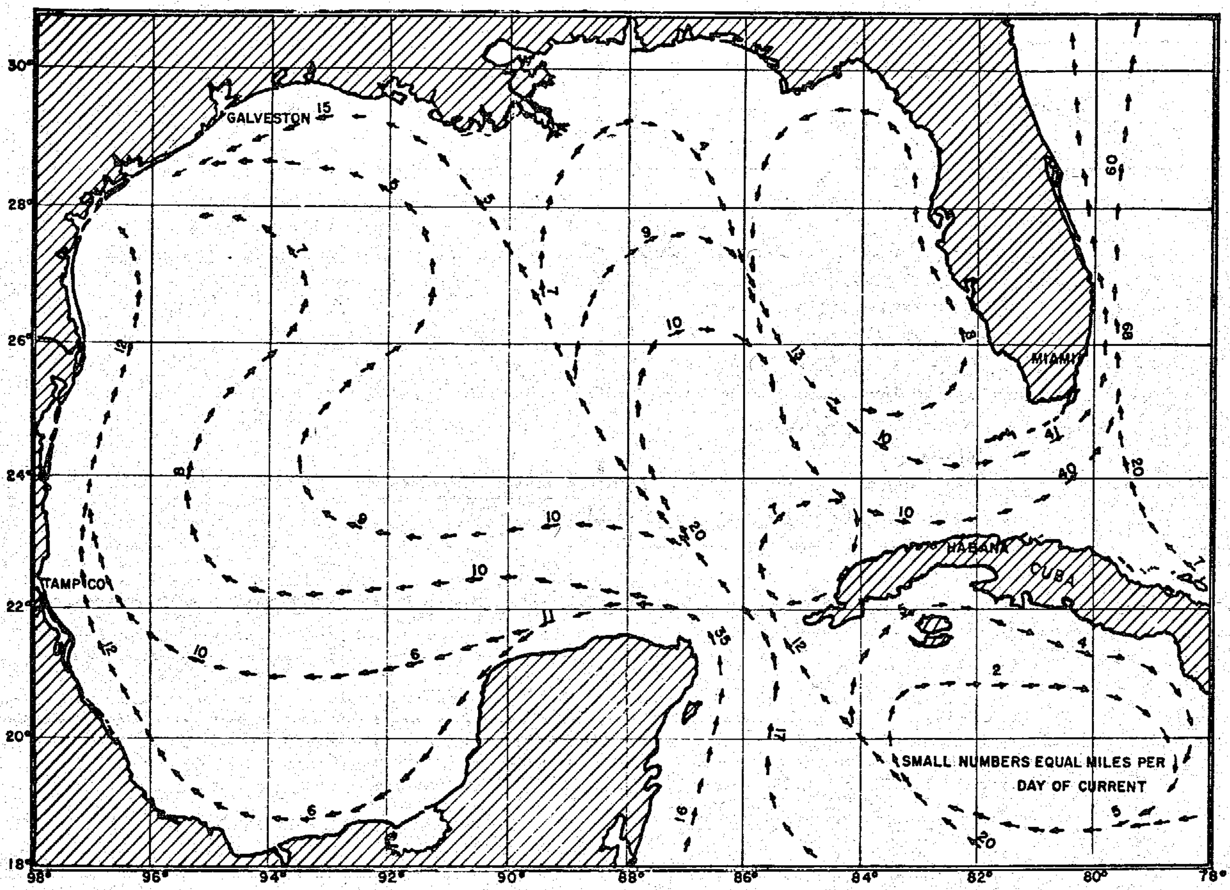


Fig. 9 - Surface currents in the Gulf of Mexico in June. (From Leipper, 1954)

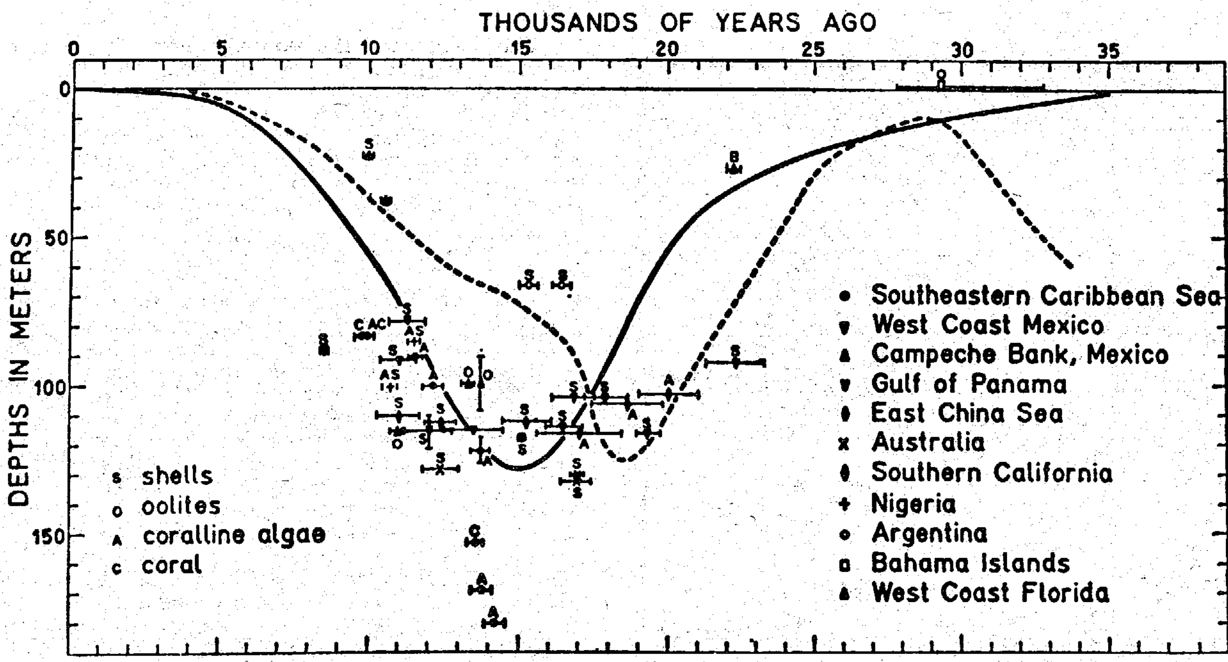
the basic climatic energy conditions; the shape, slope, and composition of the nearshore continental shelf; the tidal range and nearshore current patterns; and the importance of biologic agents in the form of both constructive and destructive features. All of these variables are superimposed upon the position of sea level itself to produce the resultant coastal system. Consequently, any barrier island system and the associated beach system is a complex product of multiple casualty.

GEOLOGY OF SANIBEL ISLAND

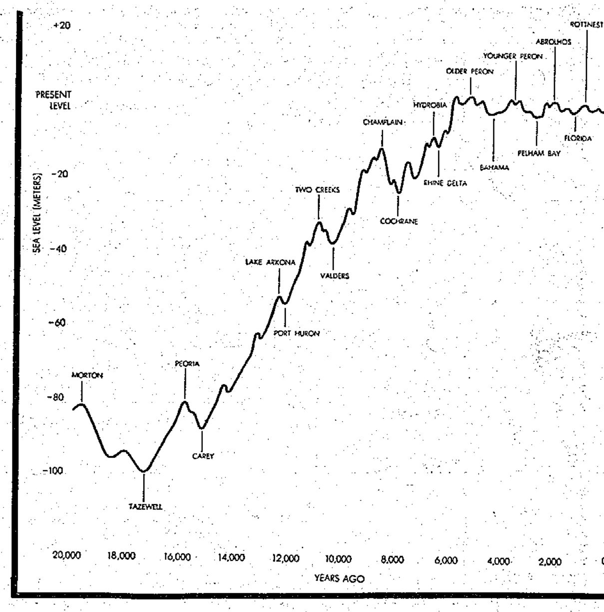
Sanibel Island is part of an extensive barrier island chain which extends from Anclote Key south to Cape Romano along the Gulf of Mexico coast of western peninsular Florida. A discussion of the origin of these barrier islands is largely an academic exercise and is not crucial to the problem at hand. Rather, what is important is the geologic framework of the barrier, the modern energy regimes operating upon the barrier, and the modern geologic processes which act in response to the energy regimes. These are the factors that must be considered in developing any management or land use plan for a barrier island.

Missimer (1973) has made an extensive study of the stratigraphy and geomorphic features of Sanibel Island, upon which I have drawn heavily for the data in this section of the paper. On the basis of 24 drill holes scattered across the island, Missimer delineates six basic stratigraphic units associated with this system (Figure 13). The basic stratigraphic section for Sanibel Island is reconstructed on the basis of various published reports and is briefly summarized in Table 3. The stratigraphic sequence outlined in Table 3 is essentially identical to that developed in a very detailed study of the barrier island-nearshore system in the Indian Rocks area by Winston, Riggs, O'Connor and Brueninger (1968). A geologic map of the Indian Rocks area and generalized geologic cross-sections through the barriers are presented in Figures 14 and 15 (Riggs and O'Connor, 1974).

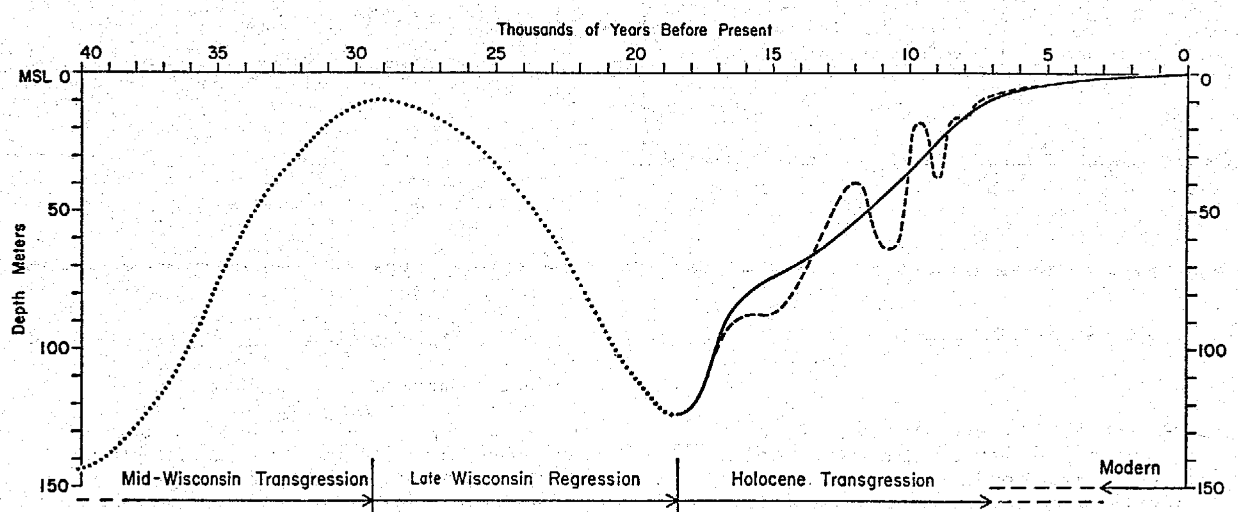
Missimer's (1973) study of Sanibel Island included an extensive analysis of the geomorphic features. The entirety of the Island consists of at least 10 and possibly 12 sets of beach ridges, each set containing a variable number of individual ridges. Figure 16 shows the orientation of 10 recognizable sets of ridges numbered from oldest (number 1) to youngest (number 10) and demonstrates the varying orientations of the sets as well as the truncation of older sets by younger sets. The oldest obvious beach ridges, Set 1, are presently occurring below sea level and in the intertidal zone where they are being buried by modern muddy sands and 2 to 4 feet of peat resulting from deposition within the intertidal marshes and swamps. Missimer



Depths and ages of sea-level indicators throughout the world. The solid line is the sea-level curve for the Atlantic continental shelf. The dotted line is the sea-level curve for the Texas shelf.



Rise in sea level from 17,000 to 6,000 years ago is the most rapid upsurge yet identified in the geological record. The floods that accompanied this 100-meter increase are believed to be the subject of the deluge legends of ancient peoples. The names on the curve indicate the locations where the principal oscillations in sea level were discovered, or where their shorelines are most prominent. Sea level has remained relatively constant for the past 6,000 years, and the amplitude of short-term oscillations is diminishing.



Late-Quaternary fluctuations of sea level, from compilation of published and unpublished radiocarbon dates and other geologic evidence. Dotted curve estimated from minimal data. Solid curve shows approximate mean of dates compiled. Dashed curve slightly modified from Curray (1960, 1961). Probably fluctuations since 5,000 B.P. not shown here.

Fig. 10 - Three published opinions of sea level fluctuations of the past 20,000 to 40,000 years. (Reproduced from Fairbridge, 1960; Milliman and Emery, 1968; and Curray, 1965, respectively)

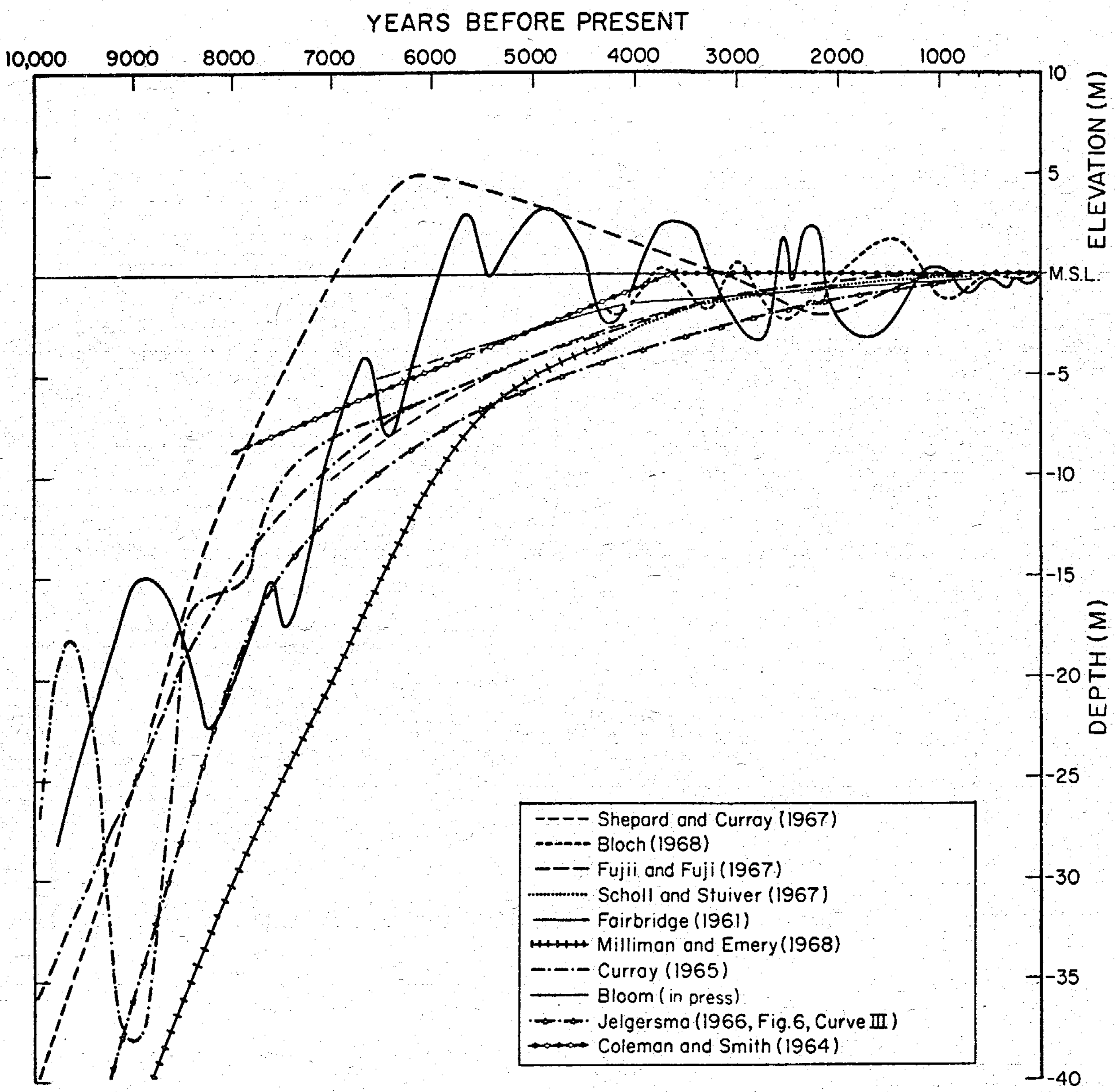


Fig. 11 - Comparison of a few of the published opinions on sea level fluctuations for the past 10,000 years. (From Curray, 1969)

believes that these older beach ridges were formed when sea level stood 6 to 8 feet below its present level. The other old sets of ridges are still above present sea level, but the differential relief between the ridges and swales is being diminished with time due to vegetation growth and the flooding processes during intense hurricanes. This slow filling of the swales with fine-grained sediments makes the ridges indistinguishable on the ground.

Each set of beach ridges may contain upwards to 80 (in Set 5) individual beach ridges. Missimer believes that an individual beach ridge may be the product of a whole series of events or storms. Thus, it appears that each set would reflect a time system which had a similar set of conditions. When conditions change, a new set of

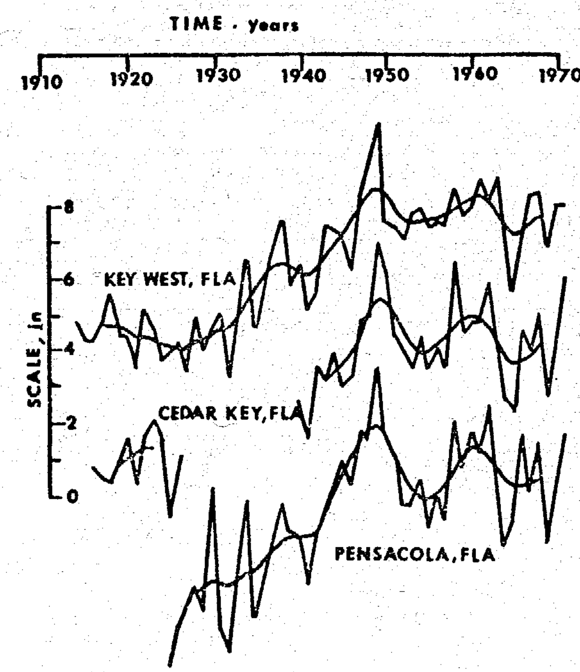
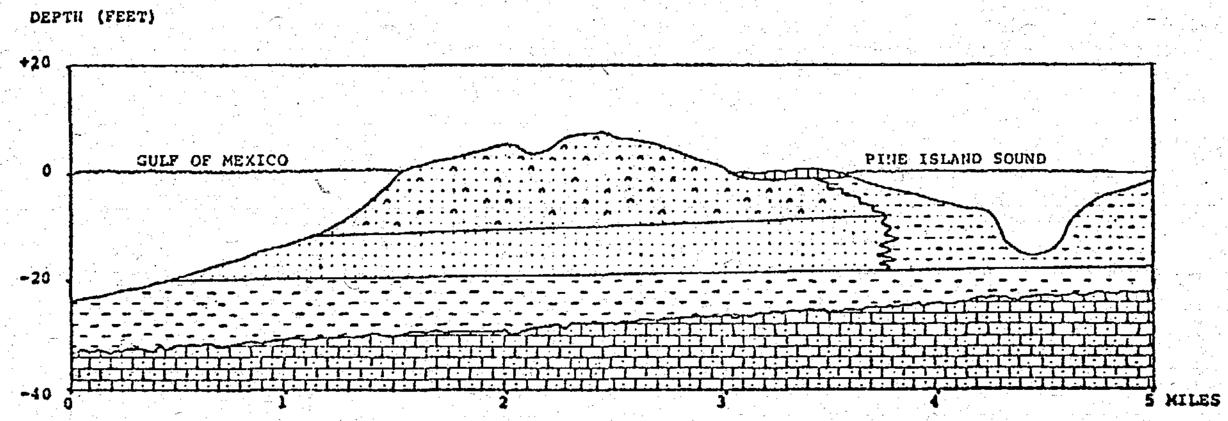


Fig. 12 - Recent changes in sea level as recorded by tidal gauges in eastern Gulf of Mexico. (Modified from Hicks by Brooks, 1973)

erosional and/or depositional processes develop with subsequent erosion and truncation of the old set. Another change will bring about the deposition of a new set of ridges with an entirely different orientation. Brooks (1973) believes that each set of beach ridges corresponds to definite climatic events with the periods of erosion and truncation being related to warm climatic periods.

The present Sanibel Island shoreline is one of truncation of older beach ridge, Sets 5 through 9, except along the northwestern portion where set 10 is presently forming (Figure 16, which appears as Figure 6 in the Hydrology Appendix). However, this shoreline of truncation does not appear to be presently undergoing a significant amount of shoreline erosion, nor has there been any during the past 117 years as indicated by U.S. Army Corps of Engineers shoreline studies (Figure 17). This takes on increased meaning when considered in light of Missimer's first approximation that Sanibel has had a progradation rate of between 2.5 and 5 feet per year throughout its 4,000-to-5,000-year history and which includes extensive periods of erosion. Some deposition and accretion is presently taking place just south of Blind Pass in ridge Set 10 (Figures 16 and 17). Missimer believes this set has been active for the past 200 years. The remainder of the Sanibel Island shoreline seems today to be in a delicate state of balance whereby neither erosion nor truncation is presently taking place. However, neither is significant deposition nor accretion. This present delicate balance could very easily be upset by man's activities or by some major change within the natural energy or sediment regime of this coastal system. There are too many variables and they are too complex and poorly known to begin to predict any natural changes which might disrupt this delicate balance. However, by knowing something about the effects of development upon the coastal processes, we can to some extent control this variable and possibly keep man's effects to a minimum. A major conclusion from Missimer's study (1973) that must be kept in mind is that "...the deposition of Sanibel Island is not a continuous process with time, but was intermittent in nature with periods of deposition and of intensified erosion."



Modern Estuarine Sediments		Recent Peat Deposits
		Recent Estuarine Deposits: Organic Matter, Sand, Mud, and Shell
Shelly Sand Unit		Oxidized Barrier Sand and Shell
		Unoxidized Barrier Island Sand and Shell
Muddy Shelly Sand Unit		Relict Estuarine Deposits: Organic Matter, Sand, Mud, and Shell
Pleistocene Limestone Unit		Pleistocene Sandy Limestone

Fig. 13 - Idealized section of Sanibel Island perpendicular to the island axis. (Modified from Missimer, 1973)

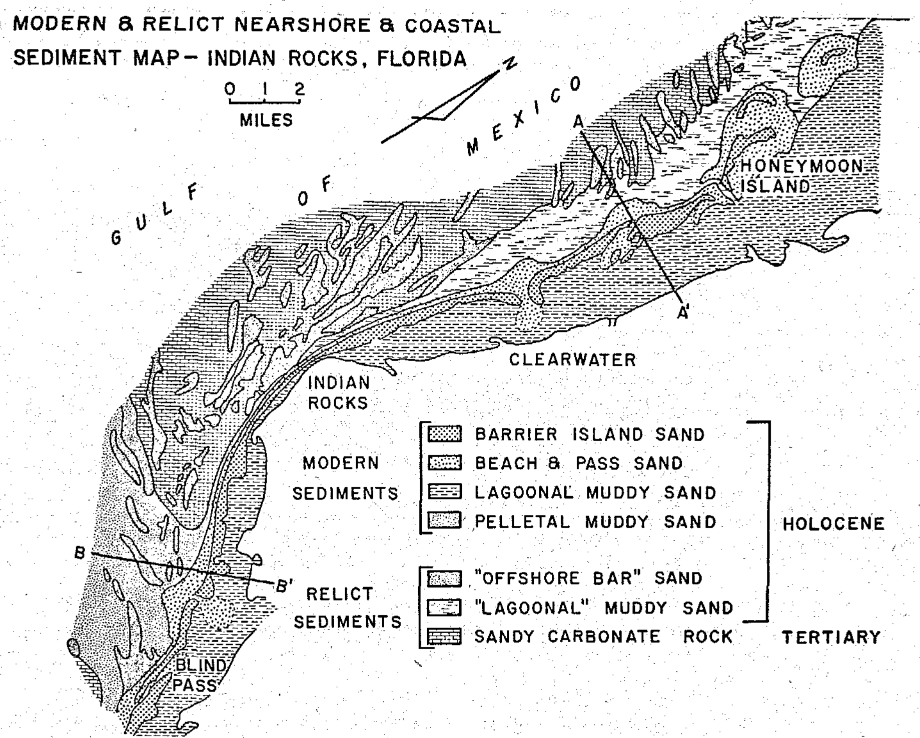


Fig. 14 - Geological map of the coastal zone, Indian Rocks, Florida. Cross-section locations A-A' and B-B' refer to Figure 15. (From Riggs and O'Connor, 1974)

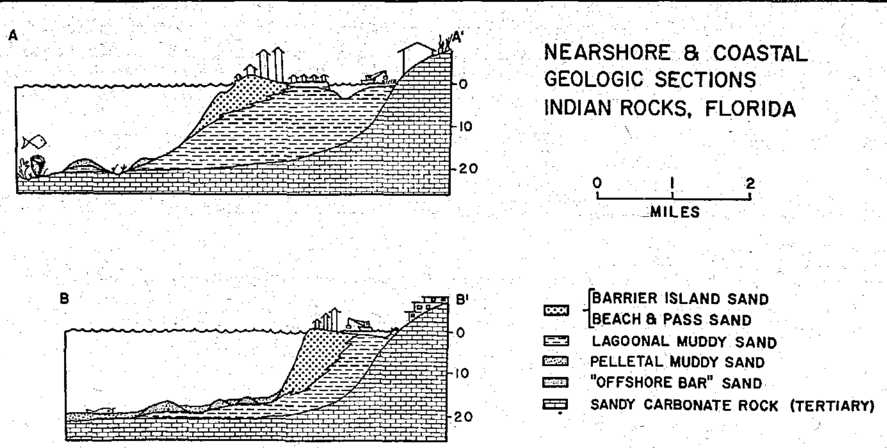


Fig. 15 - Generalized geologic cross-sections of the coastal zone, Indian Rocks, Florida. The location of the cross-sections is given in Figure 14. (From Riggs and O'Connor, 1974)

GEOLOGY OF THE NEARSHORE SHELF

Detailed geologic information of the nearshore shelf off of Sanibel Island is extremely limited. However, on the basis of the following studies and information, a pretty good idea of the geology can be developed:

a. The U.S. Army Corps of Engineers (1969) drilled 15 shallow (15 to 30 feet) holes about 1800 feet offshore of Captiva and Estero Islands on either side of Sanibel. Figures 18 and 19 show geologic cross-sections through the holes in the southern Captiva area and in the northern Estero area respectively.

b. Missimer (1973) worked with 24 drill holes on Sanibel Island, defined the surface stratigraphy of the Island (Table 3), and constructed an idealized geologic cross-section across the island and onto the nearshore shelf (Figure 13).

c. I made a detailed study of a very similar coastal system in the Indian Rocks area to the north (Riggs and O'Connor, 1974 and Winston, Riggs and O'Connor, 1968). This study included surface mapping and process-response studies, both utilizing extensive SCUBA diving, and subsurface stratigraphy based upon shallow coring. The geologic map is presented in Figure 14 and several generalized stratigraphic cross-sections are presented in Figure 15.

The basic stratigraphy of Sanibel, as described by Missimer (Figure 13), can be roughly correlated with the offshore holes of the Corps of Engineers. The section for Sanibel, as defined in Table 3, is almost identical to that which we defined for the Indian Rocks coastal system (Figures 14 and 15). In the latter area, we traced the units with drilling from the modern estuaries, below the barrier, to the nearshore shelf where each unit was successively exposed down the forebeach slope. The geologic map of the nearshore (Figure 14) shows the outcrop pattern of each of these units and demonstrates the relationship to the composition of the exposed surface sediments.

Considering Figures 13, 18 and 19, the nearshore geology of Sanibel Island can be realistically reconstructed as follows. The shelly sand unit (Table 3) extends down the high-energy upper forebeach slope to water depths of 12 to 15 feet which occur between one-fourth and one-half mile offshore. Below this major slope change, the muddy shelly sands are exposed. These fine-grained sediments would extend seaward possibly to the area of the 24-foot contour, between one and two miles offshore. This portion of the seafloor is not affected by the day-to-day energy levels of the Gulf. Consequently, these fine-grained sediments are exhumed primarily by biological erosion processes until periods of high-energy storms when the loosened fine-grained sediments are eroded by physical processes and interact laterally with the sediments on the forebeach (Riggs and O'Connor, 1974). Very little topography generally occurs within this section of the lower forebeach. Seaward of the 24-foot contour area is a fairly extensive system of northwest-southeast trending ridges with up to ten feet of relief, and composed of clean, fine-to-medium-grained shelly sands. The ridge and swale structures should be extensively explored as a possible source of adequate grain size sediment for beach nourishment projects. This basic sequence of sediment patterns was generally outlined by Gould and Stewart (1955) in their broad regional study of sediments of the shelf floor (Figure 20). In the swales between the ridge structures are extensive outcrops of the Pleistocene shell beds and soft fossiliferous limestone (Table 3). The extensive exposures that occur in this nearshore area (Brooks, 1975, personal communication) probably begin to outcrop in the vicinity of the 30-foot contour and extend seaward (Figure 21). These rock surfaces provide a substrate for prolific coral and sponge growth, along with the abundant

Table 3 - Generalized stratigraphic section of Sanibel Island. See Fig. 13 for the stratigraphic and geographic position of each unit within the Sanibel Island system. (Modified from Missimer, 1973; Brooks, 1964; and Huang and Goodell, 1967)

<u>MODERN ESTUARINE SEDIMENT UNITS</u>	
Peat	Extensive mangrove swamps and <u>Spartina</u> marshes occur around the estuarine perimeter of Sanibel Island and produce thin and irregular accumulations of organic plant debris. These deposits are presently being formed within the intertidal zone and extend down to about 4 feet below MSL.
Muddy Shelly Sand	The modern estuarine sediments are primarily fine-grained quartz sand with variable amounts of silt, clay, shell material, and organic matter. These modern sediments are extremely variable in thickness and depth.
<u>SHELLY SAND UNIT</u>	
Upper Bed	Tan oxidized unit composed of mixed carbonate shell material and fine to medium grained quartz sand. The shell material in this unit ranges from 10% to 90% and averages 50%, and contains abundant <u>Donax</u> <u>variables</u>. This is the surface unit on Sanibel Island and varies from about 10 to 20 feet in thickness.
Lower Bed	Gray nonweathered fine shelly sand. The sand is slightly finer grained and the fine shells are unaltered. This unit everywhere underlies the upper shelly sand unit and has a maximum thickness of 10 feet.
<u>MUDDY SHELLY SAND UNIT</u>	
Upper Bed	An interbedded sequence of muds and muddy shelly sands with some organic matter. The shells include abundant <u>Cardita floridana</u> and <u>Anomalocardia</u> <u>cuneimeris</u> with some <u>Crassostrea virginica</u> shells at the base. This unit underlies the shelly sand unit and varies from 0 to 18 feet in thickness.
Lower Bed	A shelly sand bed with some mud which generally occurs on top of the limestone. It varies from 2 to 8 feet thick where it occurs and contains up to 50% shell material along with abundant limestone rock fragments.
<u>PLEISTOCENE LIMESTONE UNIT</u>	This unit ranges from an indurated and weathered fossiliferous, sandy limestone with abundant solution features under Sanibel Island to a nonindurated unweathered sandy shell bed on the nearshore shelf. It generally occurs between 20 and 30 feet below MSL.

associated modern reef fauna and flora. The organisms associated with the soft limestone surfaces are actively and rapidly corroding and eroding the surfaces producing "new" sediment which consists of clastic terrigenous grains, limestone rock fragments, fossil shell material, and modern bioclastic shell material. This material is then contributed to the modern sediment regime during high energy storms. The modern exhumation and erosion of the fossiliferous Pleistocene limestone and relict estuarine and open bay sediments in the nearshore area, as well as the associated bioherms and reefs growing on the offshore rock surfaces, are extremely important to Sanibel Island for two basic reasons:

1. This is the only major source of "new" sediment which is being supplied to the modern barrier island system.

2. This is probably the major source of much of the modern and fossil shell material that ends up on the Sanibel Island beaches.

Both of these represent important natural resources to Sanibel.

The sediment sequences within the Sanibel area suggest that the barrier formed considerably seaward of its present location on the Pleistocene limestone surface during a lower stillstand of the sea. With the continued rapid rise of the Holocene sea, the barrier system has migrated up and over the open bay and estuarine sediments to near its present position. As sea level rise began to slow down 4,000 to 6,000 years ago (Figure 11), Sanibel was generally in its present location, but did not have its present shape. The history since this time has been well documented by the detailed beach ridge studies of Missimer (1973). He concludes that the oldest sediment patterns suggest that Sanibel Island was then modified into a southeastward prograding and accreting spit extending off of the barriers to the north. As the northern Lee County barriers slowly

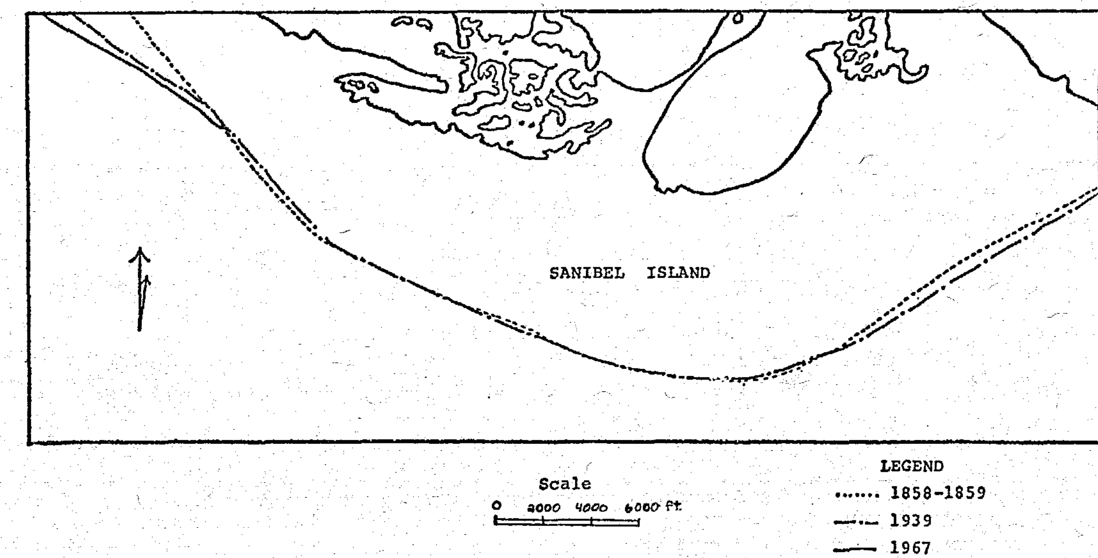


Fig. 17 - Positions of the shoreline of Sanibel Island in historical times. (From Missimer, 1973)

receded in response to a slowly rising sea level, the southward-moving longshore currents deposited the sediment as prograding spit-like features. Periodic changes within the sediment and/or energy regimes of the coastal system caused Sanibel to have a multi-phase depositional history with alternating periods of deposition and beach ridge accretion and erosion and beach ridge truncation.

Geologic Processes of the Coastal Zone

BEACH DYNAMICS

The zone where the ocean comes in contact with the land is known as the beach. The beach zone is much more than just the area between mean low and high tide; it includes the entire forebeach slope of the nearshore shelf and extends inland across the backbeach and above the storm beach to the dunes. When composed of unconsolidated sand, this broad zone is totally flexible and molds itself to the energy regime of the ocean that is operating upon it at any given time; this energy regime is both complex and extremely variable. The beach responds to any energy change to produce a three-dimensional profile that is in equilibrium with that specific energy regime. Thus, any sand beach has a specific set of responses to any set of processes and begins to change as soon as a disequilibrium appears. The sand is shifted back and forth expanding and contracting the beach zone in direct response to the disequilibrium established by a change in specific energy conditions. During high-energy periods, which may be a single storm or a seasonal pattern, increased wave heights require a broad offshore sand apron and offshore bar system to break the wave energy prior to reaching the swash zone. Consequently, great quantities of sand are pulled off the backbeach and stored offshore; this produces a narrow and steep backbeach commonly called a winter beach. As the energy abates, the lower wave heights do not require the extensive offshore sand apron and bar system. The sand which is temporarily stored offshore as an energy absorber slowly migrates back up the beach face as one or more ridge and runnel structures, and is ultimately welded to the backbeach face. The runnel is rapidly lost, producing a broad shallow beach, commonly called a summer beach.

During periods of extremely high-energy levels on a beach, the dunes themselves become the storm berm and washover becomes an active process. The water breaking over the top of the storm berm carries a significant amount of sediment over the back side of the storm berm or dune field to produce a broad structural overwash apron. Overwash is an important structural part of the storm beach and, on many barriers, is the basic mechanism for the construction, maintenance, and migration of the backside of the island. This overwash process has been described in considerable detail by Dolan (1972 and 1973), Dolan, et al., (1973), and Godfrey and Godfrey (1973). Overwash is normally associated with a migrating or retreating barrier island in which the sediment supply is not adequate to maintain a stable shoreline or produce an accretionary situation. A rapidly rising sea level may also be the determining factor as to the importance of overwash in any given system. In the case of Sanibel Island, there apparently has been in the past an abundant sediment supply to go with the slowly rising sea level. Thus, the island has generally grown upward and accreted seaward through time. Under these conditions, overwash as described by the work of Dolan and Godfrey, does not play the same role of island

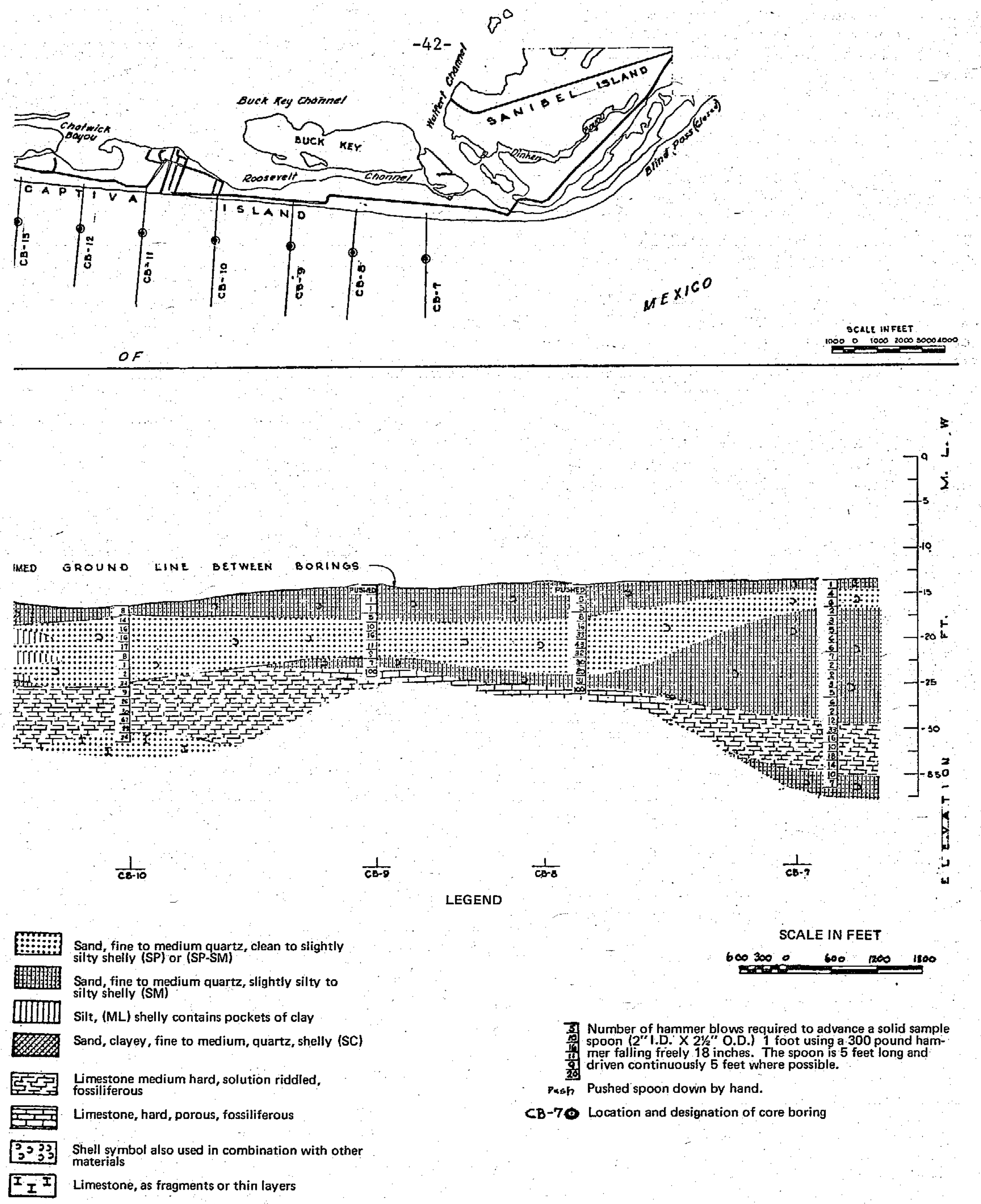


Fig. 18 - Geologic cross-section of the nearshore shelf off of Captiva Island, Florida. (From U.S. Army Corps of Engineers, 1969)

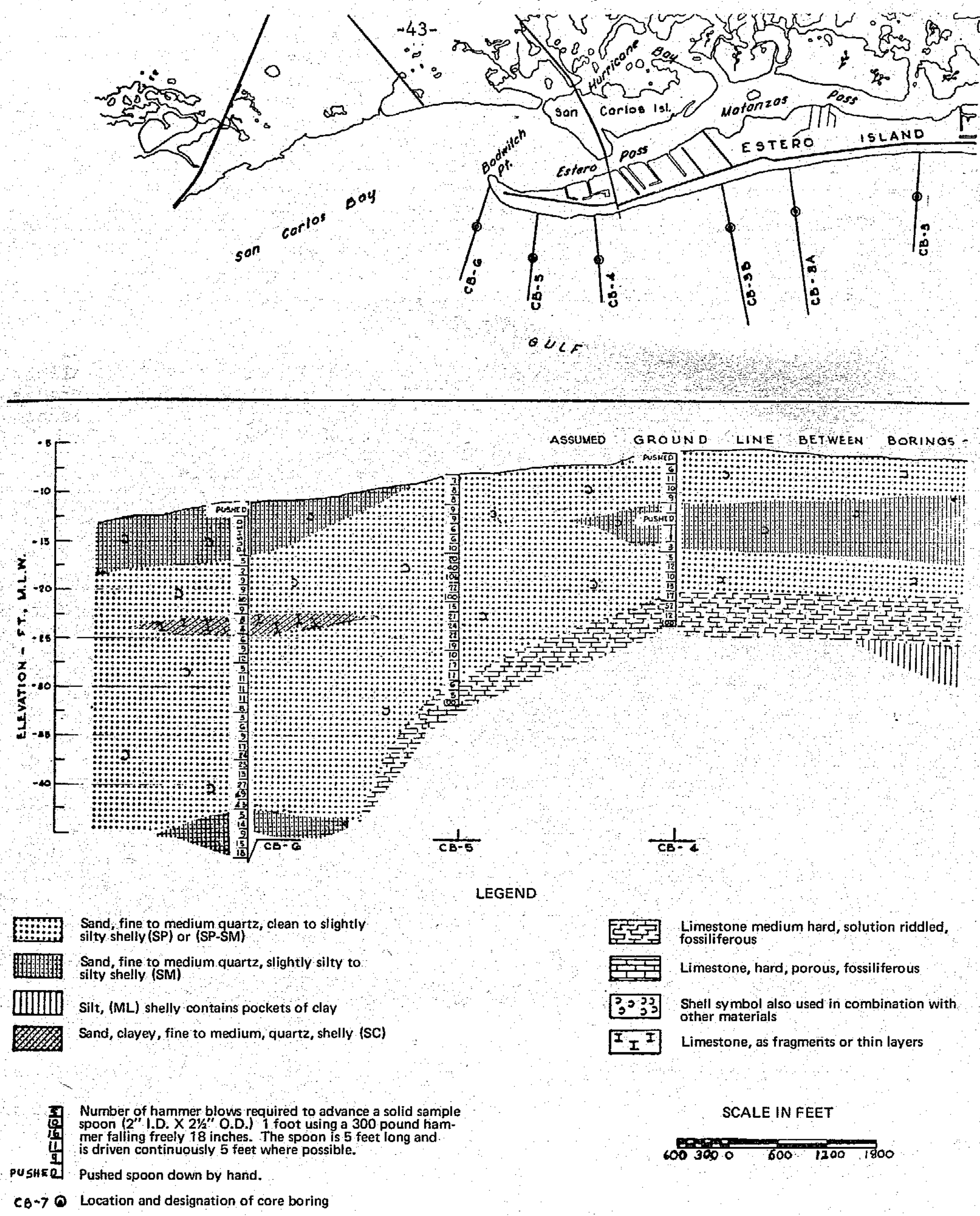


Fig. 19 - Geologic cross-section of the nearshore shelf off of Estero Island, Florida. (From U.S. Army Corps of Engineers, 1969)

maintenance and migration as it does on some of Sanibel's neighboring barrier islands. Rather, on Sanibel, the role of overwash is that of maintaining a structural berm during major storms. The consequence is a sediment filling of the swales which decreases the relief between the ridges and adds structural support.

A beach system is a three dimensional unit. Therefore, beach equilibrium profiles include the areal shoreline geometry as well as the vertical profiles already discussed. The shoreline geometry does not have the same rapid time response that the vertical profiles have. Rather, changes in an areal profile represent responses to longer term seasonal wind and littoral drift patterns, sediment supply or lack of and, most important, to the dynamics of associated inlets.

Sand beaches are seldom straight but consist of sinuous curves and bulges called sand waves. The wave length varies from 100 meters up to 1,000 meters with amplitudes of 10 to 25 meters. Dolan (1971) found that sand waves have a definite rhythmic pattern and rate of migration along the shore in response to the littoral drift and storms. The focus of any shoreline erosion is a direct function of the position and phase of the sand wave fields. In addition to these intermediate sand waves, there are larger cuspate structures associated with most sand beaches which are usually related to inlets and inlet processes.

INLET DYNAMICS

Inlets, or outlets, develop or change in direct response to the basic hydraulic system and storm pressures within the coastal system. They serve an essential role for four sets of hydraulic processes operating within a coastal zone such as Sanibel: a) as an outlet for the fresh water discharge off the land,

b) as an outlet for storm tides developed within the estuaries, c) as a buffer for storm tides generated on the ocean side, and d) as a channel for the water exchange in response to astronomical tides. The general inlet response can be summarized as follows:

1. Inlets are self adjusting in that they open up by flushing or close down by shoaling (if there is sufficient sediment available) to fit the hydraulic pressures at any given time.

2. Inlets located near rivers and carrying a large fresh water discharge are generally larger and more stable inlets with respect to both migration and opening-closing.

3. Inlets that are dominantly tidal tend to be more ephemeral units. This is because a) the lack of a constant hydraulic pressure as produced by the river discharge and b) during normal conditions tidal fluxing does not always supply an adequate hydraulic pressure to maintain an inlet (particularly if there is an abundant sediment supply) and the inlet will either migrate/or shoal over.

4. Inlets are natural safety valves in that during conditions of high hydraulic pressure (floods and/or storm tides) a new inlet will open where needed to relieve the pressure. When this abnormal pressure is released, the inlet will close up naturally. Without this ability, the barrier islands act as dams increasing flood levels and the resultant damages.

5. Inlets will commonly recur within the same general area as needed through geologic time.

Inlets, and their associated ebb and flood tide deltas or sediment fans, are major sediment storage bins for the coastal system. These deltas supply the sediment necessary to maintain an equilibrium system among all of the interacting energy regimes which come to focus at the inlet. The "loss" of sand into inlets is at most a temporary thing, and even then only where there are "new" inlets, which do not yet have tidal deltas, does this become a major process. Any sediment that is trapped in the inlet itself is ultimately moved either in or out into the tidal delta storage bins. Since the ebb currents are generally the dominant inlet force (Hayes, et al, 1973), most sand moving into an inlet will ultimately be deposited in the offshore ebb delta. The shape of the ebb delta and the sediment movement within the delta is then strongly controlled by the interaction of the ebb and flood currents with the offshore wave system and the longshore currents. The sand stored in the ebb delta is now available for littoral transport onto the downdrift beach system. Also, high-energy storms and floods flush out the inlet and move the sand laterally to be used to absorb the storm energy in the adjacent forebeach areas. Thus, an inlet system

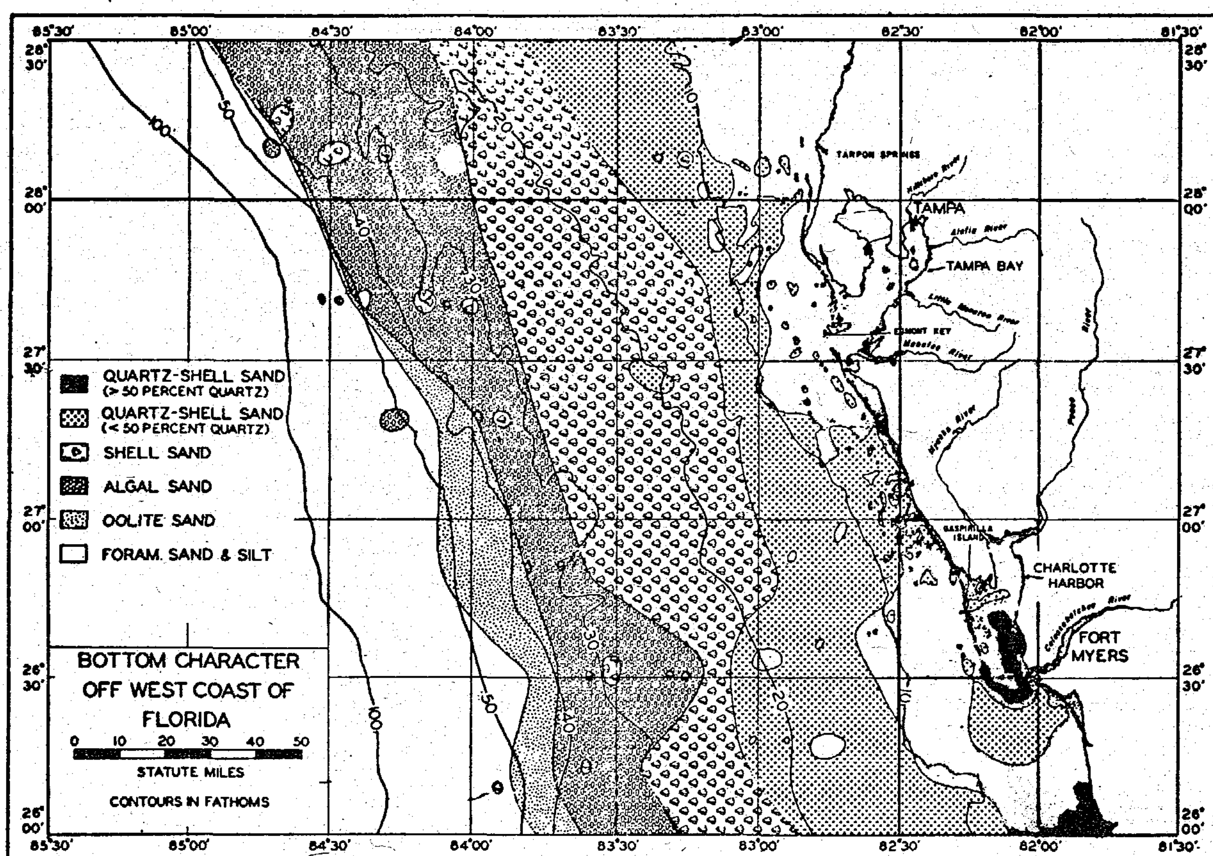


Fig. 20 - Unconsolidated sediment types on the West Florida Shelf. (From Gould and Stewart, 1955)

plays an important role in sediment storage for use as an energy sponge during storms and has built-in sediment bypass mechanisms. Consequently, inlet systems represent an integral part of the overall sediment budget of the coastal system and contribute to the overall natural ability of the system to roll with the energy punches with minimal adverse effects. Modification and/or stabilization of an inlet will limit or eliminate this ability, increasing the potential for accelerated shoreline erosion resulting from major storms.

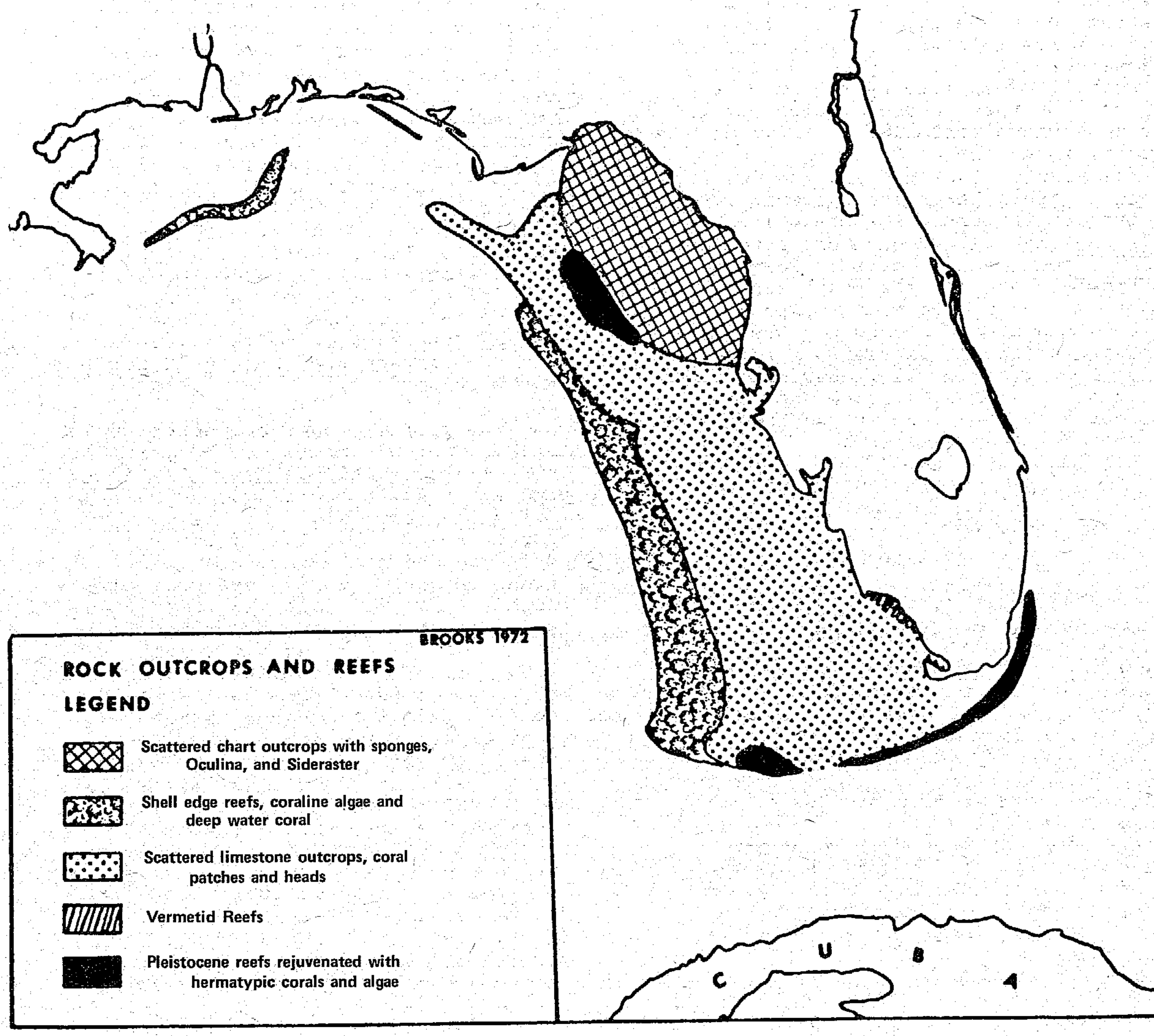


Fig. 2I - Rock outcrops and reefs in eastern gulf of Mexico. (From Brooks, 1973)

Coastal Management on Sanibel Island

BEACH MANAGEMENT

Sanibel Island is a product of and responds to the totality of geologic processes operating within the coastal zone. To live and work within the framework of this delicately balanced natural system, three most important geologic concepts must be kept foremost in the minds of all individuals and users. First, the entire region must be considered as one interacting system which includes the adjacent barrier islands, neighboring inlets, the nearshore shelf, and the marshes, estuaries, and rivers behind the barrier. A small change in any part of this overall system could have considerable effects on some other portion. Second, the cumulative effects of the actions and modifications by all users and user groups must be constantly considered. Even though the actions of one project in itself may be insignificant with respect to the overall system, by the time you accumulate ten or twenty such projects the results could be dramatic. Third, the time element is also critical in that the day-to-day processes operate under low energy situations and consequently require longtime increments for the results to become apparent. On the other hand, most significant geologic events, including responses to major modifications to the system by man, happen during the infrequent but dramatic high-energy storm situations.

Man's efforts to stabilize, develop, and occupy the beach are unfortunately concentrated in the upper portion of the beach system. This upper backbeach area is an extremely important sediment response element. It is essential in providing stability during periods of extreme wave energy. The development and efforts to stabilize this zone have these results: a) they remove the flexibility required by the natural system; b) they remove a large portion or make unavailable large sand reserves stored in the upper backbeach and the dunes; and c) they prevent the development of storm berms and overwash fans necessary to absorb the ocean energy. The inevitable consequences of the continued modification of this zone is to narrow and steepen the beach zone, thus increasing the energy expenditure per unit area of the beach. The results are a predictable increase in rates of shoreline erosion and recession during storms; this erosion is the natural response of the beach in reestablishing a profile of equilibrium.

INLET MANAGEMENT

Blind Pass has historically been an ephemeral inlet which presently has a minor tidal delta associated with it. Any ebb tide delta that formed beyond the seaward end prior to 1962, when the pass was open, was completely lost during the next decade when the pass was closed. Blind Pass opened in 1972 in response to Hurricane Agnes and is now developing a small ebb delta again. The inlet only opens and stays open when the balance of coastal forces requires it. When it is no longer required it will close. The forces causing this are not known at present, but some clues are available.

To interfere with this natural safety valve within a potentially very high energy Gulf coastal system which includes Charlotte Harbor and associate rivers, barriers, and inlets is not only geologically shortsighted, but could increase the potential danger to life and property. The latter is particularly true if we can start thinking about the consequences two, five or ten years from now instead of today. If we thoroughly and completely understood the complex interactions of the entire coastal system, then we might be justified in attempting to modify or possibly even control some integral portion of the system. But at present we are not close to that level of understanding. This point has been demonstrated time and again as efforts by the Corps of Engineers to modify various inlets have ended in disastrous results either to the inlet itself or to the up and down drift sections of the coast. For example, our experience with the attempt to open and control Drum Inlet, North Carolina, during the past three years has so far failed and has had dramatic environmental and economic consequences and it is not over with yet.

The complex interdependence of the Sanibel coastal system can be partially demonstrated by Blind Pass. The 43 percent cross-sectional closure of San Carlos Bay resulting from the construction of the Sanibel Island causeway added significant back pressure and stress to the estuarine system. It is probable that this has had some long-term influence on the reopening of Blind Pass, as well as increasing inlet erosion of the other passes through the barrier islands. There is little question that the causeway has had a major direct influence on the hydrodynamic system of the estuary, as well as the patterns of sediment movement, and estuarine erosion and deposition. A stressed system will ultimately be brought back into equilibrium when the energy system is adequate to bring about the appropriate responses. The artificial closing of Blind Pass now would probably significantly increase the stress upon the estuarine system resulting in ever-increasing erosion and instability to the other inlets of the system. In fact, any plugging of Blind Pass can only be temporary; the forces of a high-energy storm on the highly stressed estuarine system would easily blow an artifical plug out of Blind Pass. The present pattern of erosion around Blind Pass is temporary until the new inlet system re-equilibrates itself, at which time both sides of the inlet will become net depositional systems again.

COASTAL SETBACK LINES

In 1971 the Florida State Legislature enacted a bill that directed the Department of Natural Resources to develop a "Coastal Construction Setback Line along the Gulf and Atlantic shores of the State" (Coastal and Oceanographic Engineering Laboratory, 1975). As stated in the legislation, the setback line shall be determined from a comprehensive engineering study and topographic survey and based upon the following types of data:

1. ground elevations in relation to historic, storm, and hurricane tides,
2. predicted maximum wave uprush,
3. beach and offshore ground contours,
4. the vegetation line,
5. erosion trends,
6. the dune or bluff line if any exist, and
7. existing upland development.

The act states that, "upon the establishment, approval and recordation of such setback line or lines, no person, firm, corporation or governmental agency shall construct any structure whatsoever seaward thereof, or make any excavation, or remove any beach material or otherwise alter existing ground elevations, or drive any vehicle on, over or across any sand dune, or damage or cause to be damaged such sand dune or the vegetation growing thereon, seaward thereof except as hereinafter provided."

The Florida Department of Natural Resources subcontracted the Coastal and Oceanographic Engineering Laboratory of the University of Florida (COEL, 1975) to make the required studies and surveys. The criteria used to develop the setback line for Lee County can be summarized as follows:

1. A still water level storm

tide of 10.2 feet was used for computing wave uprush. The 10.2-foot storm tide level was developed by COEL through a study of the normal yearly high tides and high water levels caused by hurricanes and expressed as frequency of occurrence for a certain water level to be equalled or exceeded. The 10.2-foot figure was based on the storm tide level which has a 10 percent probability of occurrence in the next 10 years; however, such a storm can happen in any year or on any day of the storm season. The National Oceanic and Atmospheric Administration (NOAA) is currently making a storm surge study along the coast of Florida; NOAA's figure is considerably higher (12.2 feet); however, since it is only a preliminary figure it was not used.

2. A wind wave of 6 feet with a 12-second period was used as a typical hurricane-generated wave from which the wave uprush was computed for each of the surveyed beach profiles. This computation yields the information about how far landward the uprush will reach and defines the Velocity Zone: the zone where considerable structural damage can be caused.

3. Physical and vegetation indicators were developed from historical erosion data, flooding data, and topographic and hydrographic information gathered from field surveys. These indicators were utilized to adjust the computed setback line distances.

The resulting setback figure was calculated for, and measured from, each of the control monuments, which have been surveyed in at approximately 1000-foot intervals along the Sanibel-Captiva shoreline. The setback figure for each monument was plotted on a set of aerial plan photographs taken in May, 1974, and the recommended coastal construction setback line was then drawn between the plotted points.

The recommended setback line should be considered as the absolute minimum setback for Sanibel considering that a) the highest point on Sanibel Island is only about 8 feet above mean sea level and b) all of the figures used in the calculations of the line were very conservative. Buildings on barrier islands are subject not only to inundation, but also to high velocity water flow which can undermine, wash away, or collapse major structures. The buffer zone resulting from the setback line does not eliminate flooding or the resulting property damage. Rather, it will allow the beach to operate normally as well as buffer the water movement so that the damage may be somewhat lessened.

In order for the concept of the coastal construction setback line to be most effective, there must also be strong controls on the construction itself. This is now required by the Federal Insurance Administration's regulations for the National Flood Insurance Program. The requirements for this program are as follows:

1. New construction or substantial improvements of residential structures within the area of special flood hazards are required to have the lowest floor (including basement) elevated to or above the level of the 100-year flood.

2. New construction or substantial improvements of nonresidential structures within the area of special flood hazards are required to have the lowest floor elevated to or above the level of the 100-year flood or, together with attendant utility and sanitary facilities, are required to be floodproofed up to the level of the 100-year flood.

3. Existing uses located on land below the elevation of the 100-year flood in the coastal high hazard area shall not be expanded.

4. No land below the level of the 100-year flood in a coastal high hazard area may be developed unless the new construction or substantial improvement (i) is located landward of the reach of the mean high tide, (ii) is elevated on adequately anchored piles or columns to a lowest floor level or above the 100-year flood level and securely anchored to such piles or columns, and (iii) has no basement and has the space below the lowest floor free of obstructions so that the impact of abnormally high tides or wind driven water is minimized.

The high hazard area is defined as that portion of the island which would be flooded with 3 feet or more of water moving at a minimum velocity of 3 m.p.h. during the 100-year storm. The calculated 100-year storm level for Sanibel Island is 10.2 feet above mean sea level (COEL, 1975). Most of Sanibel Island would be under 3 feet or more of water during such a storm. However, the zone of high water velocities would probably be restricted to the outer perimeter of the island, to unvegetated areas, and to open roads across the island. Consequently, the broader and more vegetated the buffer zone, the more effective it will be in decreasing water velocities. The result, of course, is a decrease in the loss of property and life resulting from any given storm.

The setback line required by the State of Florida is only for the shorelines that face the open Gulf and Atlantic Ocean. However, hurricanes can have a dramatic impact upon estuarine waters resulting from the combination of the storm tides in the shallow water bodies and fresh water flooding from discharge off the land. Consequently, the flooding and storm damage can be equally as great along the estuarine shorelines depending upon the specific storm conditions. Therefore, it becomes imperative to establish a setback line for the open estuarine shorelines as well as the Gulf shoreline.

The buffer zones which result from the establishment of coastal construction setback lines serve another very important function for Sanibel Island. These areas preserved in essentially their natural state are much more available and conducive as wildlife breeding sites. Such birds as least terns, skimmers, and golden plovers, as well as loggerhead turtles, require extensive backbeach areas for successful nesting. The vegetated area above the storm beach is essential nesting habitat for smaller land birds and animals.

Conclusions

We can thus come to several fundamental conclusions about Sanibel Island, which is first and foremost a barrier island with a definite heritage:

(1) The island itself is an integral part of a much larger system of which all parts are intimately interrelated and interdependent in much the same way that the heart is to the human body. Any change or modification of some portion of the system will have some effects and responses on most other portions of the system.

(2) The island is a total product of its past geologic history and all parts of its present topography, soils, water drainage, vegetative ecotomes, etc., are a total consequence of this history.

(3) The island is presently a dynamic geologic unit in which the geologic processes which produced the island are still actively operating to maintain and/or modify the system in response to major changes of the controlling variables.

(4) The island, in its natural state, is in equilibrium with the multitude of energy regimes acting upon the system; and change in the energy regime causes geologic responses which operate to produce a new equilibrium situation for that energy regime.

(5) Since the complex set of energy variables are in constant, and not always understandable flux, the barrier island also is in a continuous state of flux in response to these changes. The barrier, which is a product of these various energy regimes, will respond to disequilibrium situations and do whatever is necessary to bring the system back into an equilibrium state.

(6) A barrier island needs "elbow room" to respond to these natural processes; significant restrictions, limitations, or modifications that are put in its way or forced upon it will either a) be eliminated by the periodic high energy regimes operating upon the system or b) modify the system to the point where the cumulative responses may bring about dramatic and undesirable long range effects including compounding the original problem.

These conclusions are founded on basic geologic facts and principles. The history of Sanibel Island during the past 5000 years is characterized by alternating periods of beach ridge development and accretion and periods of erosion and truncation. From this we can conclude the following:

(1) Sanibel Island is apparently now in a null period, except along the northwestern shore where a period of sediment accretion and beach ridge formation has been irregularly taking place for several hundred years.

(2) The process of beach ridge accretion occurs during high-energy storms and requires a natural equilibrium profile with an abundant sediment supply.

(3) Interferences with either the natural beach profile, such as the abundant construction which is presently taking place in the upper beach zones, or a major change in the sediment supply, which could very well happen as a result of the proposed erosion-control projects on Captiva Island, could rapidly change the present system to one of erosion and truncation. Thus, continued beach development or the implementation of some coastal erosion measures could have major long-term results with respect to the stability of Sanibel Island.

The technical data and basic understanding of the various energy regimes which dictate the geologic processes operating on Sanibel Island, as well as the exact nature of the geologic responses within this complex coastal system, are very poorly known. At best, the system is only known from broad regional oceanic and climatic data, a review of changes from some old aerial photos and maps to modern shoreline surveys, and very limited on-site station monitoring for tides, currents, waves and sediment movement. Therefore, recommendations for extensive engineering projects that involve major economic investments, and more importantly, involve major structural modifications of the coastal system should wait until this sketchy data base and understanding is greatly improved. Past experience dramatically demonstrates that without this approach, whatever equilibrium does exist will be disrupted and the problems accentuated, producing greater adverse consequences in the long term. Thus, in terms of long-range economics of both the natural system and man, it is better to accept the natural processes as fact and as part of a complex set of intimately interacting variables which we do not fully understand and are not capable of controlling. We must accept the natural processes and become more flexible within a totally flexible natural system. This means changing our present conventional approach to development in which building designs and layout plans are considered universal (e.g., the same Holiday Inn that is designed for Orlando would also be put on the storm beach of Sanibel Island). This approach is not adequate; the development for Sanibel Island must be designed for Sanibel Island itself and be developed around the basic processes operating within this specific dynamic natural coastal system. However, in order to implement this approach, traditional patterns of thinking must change. This includes conventional attitudes towards geologic change such as shoreline fluctuations and inlet migration; land ownership and ownership rights; land-use zoning to include broad buffer zones, hazard zones, and cluster development; and more stringent construction codes along the beach zone including building design, size, and the type of construction of homes, motels, condominiums and roads.

"The seam where continent meets ocean is a line of constant change, where with every roll of waves, every pulse of the tides, the past manifestly gives way to the future. There is a sense of time and growth and decay, life mingling with death. It is an unsheltered place, without pretense. The hint of forces beyond control, of days before and after the human span, spell out a message ultimately important, ultimately learned: now forever, mortality, infinity."

Levenson, 1973

Recommendations

The following recommendations are designed to 1) recognize the natural geologic processes that are continuously operating along the coastal system of Sanibel Island, 2) establish a set of specifications necessary to preserve the coastal system in a healthy, stable, and non-stressed state, and 3) allow man to develop and use this unique natural system within the bounds and limits established by the processes of the system itself; i.e., in a fashion which will allow the greatest safety for life and property. The following considerations are recommended:

(1) Establish rigid "stress limits" to stabilize the disproportionate growth and development of Sanibel Island. This should include the type, rate and magnitude or total carrying capacity that the island can handle without major effects upon the natural systems and it should be done now before development has progressed any further.

(2) Develop a setback plan for construction and which conforms to the requirements of the Florida legislation and should include the following:

(a) The setback lines as recommended by the Coastal and Oceanographic Engineering Laboratory (1975) should be adopted as absolute minimal construction setbacks for the Gulf coast.

(b) Develop a setback line for construction along the entire estuarine shoreline of Sanibel. Due to the extremely different character and variability of the estuarine shorelines and the processes operating upon them, this will be a difficult task and the resulting setback lines will be much more variable.

(c) All structures seaward of the setback line including buildings, seawalls, roads, etc., should be identified as non-conforming and scheduled for eventual termination.

(d) The beach sand ridge ("dune-field") should be re-established wherever it has been removed and all areas between the setback line and the natural vegetation line should be revegetated. This vegetative cover should be of the native species that have the appropriate salt spray and other environmental tolerances to withstand storm effects.

(e) Sanibel Island should enter the National Flood Insurance Program and agree to adopt and strictly enforce floodplain management regulations for all new construction and substantial improvements of structures that fall behind the construction setback line and still fall within the coastal high hazard area as defined by the Federal Insurance Administration.

(f) The adopted setback plan should be followed strictly insofar as new construction is concerned. If such a setback plan is carried out, it will 1) provide a natural storm buffer or shock absorber which will minimize property damage and loss of life resulting from major storms, 2) allow the beach system to have the necessary "elbow room" to maintain an equilibrium profile, which includes erosion and accretion, without economic barriers, and 3) provide a natural area for nesting shore birds, turtles, and other forms of wildlife.

(3) With the establishment of an adequate setback plan, the natural and fluctuating beach processes of erosion and accretion along the Sanibel shoreline should not need correction. Thus, the use of existing buildings and roads that fall within the buffer zone, and become threatened by erosion or act in any fashion to modify the equilibrium profile of the beach, should be terminated as quickly as possible so that the shoreline equilibrium can be re-established.

(4) If shoreline erosion of Sanibel Island becomes a dominant process and extends the beach behind the defined buffer zone such that it is determined that erosion control is necessary, then vertical and lateral equilibrium profiles should be re-established through beach nourishment. Fixed structures which distort the natural shoreline profile or which extend beyond the natural storm beach (i.e., groins, jetties, seawalls, and bulkheads) should not be used.

(a) Sediment for any beach nourishment program should not be mined from within the active beach system as presently proposed for Captiva Island. The active beach extends from the beach ridge and storm ridge to the seaward limit of the lower forebeach (about the 20 to 24-foot bathymetric contour) and thus excludes the proposed source areas within the ebb tidal deltas and the middle forebeach.

(b) All sediment used for

beach nourishment should be texturally compatible with the existing energy regime and not just filler material. It should have the same textural characteristics as the present natural beach sediments; this also excludes the middle forebeach area as a potential source area as is presently proposed for Captiva Island.

(c) The offshore ridges, that occur seaward of the 24-foot bathymetric contour, should be explored as a potential source of texturally compatible beach nourishment sediment. This sediment should also have a high shell content; thus, it would also nourish the important shell resource of the beaches.

(5) Blind Pass is a very dynamic coastal element which historically has gone through dramatic changes and will continue to do so.

(a) Blind Pass, and the land immediately adjacent to the Pass which is subject to the geologic changes of the pass, should be declared a natural hazard area in which the geologic processes are allowed to operate in response to the changing energy regimes without any interference; that is, within the defined boundaries no further development should be allowed and existing structures that occur within the special hazard area should be relocated.

(b) The permanent access road and the bridge between Sanibel and Captiva Islands should be relocated when possible from the active mouth of Blind Pass to a location well inside the inlet. This would eliminate a major and vulnerable "economic barrier" which demands protection and consequently modification of Blind Pass and adjacent areas.

(6) The people of Sanibel Island should obtain a voice and participation in the decision-making process concerning beach erosion control for Captiva Island. The justification for this is simply that Captiva and Sanibel are intimate partners of a single interacting coastal system and Sanibel will experience and share the long-term consequences, whether good or bad, of whatever is done on Captiva. This "economic barrier" is having a very definite long-term adverse impact upon the rates of shoreline change by modifying the equilibrium profile sands and they should not be obtained from the active forebeach nor from the tidal deltas of either Blind or Redfish Passes, except for that obtained from navigational dredging, as presently proposed. Rather, the nourishment sand should be obtained offshore beyond the active forebeach (beyond the 20 to 24-foot bathymetric contour).
of the beach system. The following recommendations concern the erosion controls proposals for Captiva Island:

(a) Discourage any modification to Blind Pass including closure, relocation, or structural stabilization, until an extensive study of both sediment and water dynamics of the inlet and associated coastal system can delineate the long-term consequences of such action. Until then the inlet should be allowed to operate naturally in response to changing energy regimes. The net sediment movement off Captiva Island will continue with or without the inlet, and the downdrift consequences of closure or modification could be severe to Sanibel Island.

(b) Encourage Captiva Island to relocate the shoreroad to the backside of the island along with the appropriate connecting bridges. Under present conditions, all efforts to save the road are only stalling actions.

(c) If beach erosion measures continue to be considered essential, then the use of beach nourishment should be encouraged as previously recommended. The nourishment sands should be of the same grain size as the natural beach

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APPENDIX 4

APPENDIX 4

WILDLIFE ECOLOGY

by John B. Morrill, William K. Byle, Jr., and Richard Workman

This report reviews the wildlife of Sanibel including amphibians, reptiles, birds and mammals with emphasis on the characteristics, populations, and interactions of species that directly or indirectly:

1) maintain the integrity of Sanibel Island's ecological systems.

2) provide significant benefits to Sanibel's residents and guests.

3) are protected by law or otherwise given special consideration for their inherent or acquired status.

SUBSYSTEMS

Our approach to the subject is to discuss Sanibel's wildlife separately for each major ecological subsystem recognized by The Conservation Foundation's natural system study team.

These subsystems, or zones, are physiographic provinces based on physical and vegetative characteristics. In reality, many animals move readily from one zone to another in response to their biological needs and environmental pressures.

The Gulf Beach Subsystem (about 650 acres) begins with the Gulf Beach dunes and extends 300 feet offshore (boundary of city jurisdiction).

The uplands (interior ridges) subsystem (about 1600 acres) includes areas not flooded by seasonally high water levels.

The Interior Wetlands Subsystem (1857 acres) includes the interior lands flooded by seasonally high fresh water levels.

The Mangrove-Estuarine Subsystem (about 5400 acres) includes tidal swamps, marshes, salt-water tributaries, tidal embayments and peripheral tidal flats.

The sections that follow discuss the nature of the system and the subsystems, their status as wildlife habitats, the biology and significance of selected wildlife species, their status and requirements. This discussion is meant to illustrate situations, problems and concepts.

SUMMARY OF INFORMATION

The species, their abundance, their food and habitat preferences and their seasonality have been reviewed by Hewitt (1975), Campbell (1975), Heald and Tabb (1975) and Morrill and Byle (1975). Additional inventory data are recorded by the J.N. "Ding" Darling National Wildlife Refuge and the Audubon Society's Christmas Bird Counts of Sanibel-Captiva. A general summary of the information resulting from these is given in Table 1. Food preferences are summarized in Table 2. Species that are rare, threatened, endangered, are listed in Table 3; those that require special consideration because they are restricted to specific habitats are shown in Table 1.

RELATIONS TO MAN

Historically, the wildlife of Sanibel has been highly valued by both residents and visitors. Following the establishment of the J.N. "Ding" Darling refuge on the island, the numbers of visitors increased. In 1960, 167,500 people visited the island according to the annual narrative reports of the refuge. By 1975 the estimated total number of visitors to the refuge was 829,800 with 160,711 visiting in March alone.

That shelling and wildlife are the island's major attractions are reflected not only in the refuge visitor activity reports but also in the space and classified ads of the island's two newspapers. For instance, in the 15 March 1974 Island Reporter more than 50 percent of the 211 ads were related to the island's natural resources. Of the space ads 50 percent included motifs of wildlife, beaches, fish and shellfish. Thus both the tourist and permanent resident businesses are oriented to a large degree in serving a public that is attracted to the island for its natural amenities. But the natural systems have been seriously degraded and the natural resources depleted by unconstrained development.

A variety of ecological, behavioral, and human value parameters (summarized in Table 4) should be kept in mind when planning for the conservation of wildlife. "Impact-response" matrices given in Table 5 reveal how well different species adapt to man-dominated environments.

In addition to the physical loss or alteration of natural habitats and the creation of new habitats such as ponds, lakes, roadsides, and exotic vegetation, the numbers and diversity of wildlife are being affected by the activities of people seeking to observe wildlife as though they were in a city zoo. This prevailing ignorance of the ecological needs of individual species makes specific plans for conservation difficult to formulate.

Obviously, the maintenance of appropriate habitat is the basis for healthy wildlife systems. Accordingly, we have indicated a number of valuable wildlife species and their habitat requirements. However, there is still a great need to better understand Sanibel's wildlife systems and their requirements.

An imaginative and creative educational program for the island's residents, businesses, and visitors appears to be sorely needed and long overdue. While modern landscape engineering and land-use programs are vital for maintaining and conserving the island's amenities, they may not suffice without an informed public. This might include the establishment of an active wildlife and natural resources educational program to include a visitor orientation center, trailside museum, and guided tours. Ideally, an orientation center with audiovisual exhibits should be located at the end of the causeway on Sanibel.

The whole island should be appropriately posted. Major wildlife crossings should be indicated with signs along the roads, particularly Captiva Road, where alligators, river otter, and other wildlife are known to cross the roads frequently. Known nesting sites of anhingas, osprey, loggerhead turtles, burrowing owls, terns, black skimmers, and other wildlife should be posted with information signs, especially during the breeding season. Similarly, major nesting and feeding areas of shore birds should be posted.

The need for a city natural resources department should be recognized--major functions would include monitoring, research and management of wildlife and their resources. For years this role has been admirably filled by the Sanibel-Captiva Conservation Foundation, but this group has no formal power to regulate or otherwise act in the public interest.

Faunal Inter-relationships

While Sanibel is first and foremost a barrier island, it is part of a larger ecological system. Barrier islands offer an environment for wildlife that differs from the mainland and consequently the species mix and abundance pattern is distinctive. Sanibel's geographic location and geological development have resulted in a special combination of subsystems providing diverse wildlife habitats. Wildlife that come to the island find refuge in isolation from mainland conditions and may rapidly expand their populations.

Geographically, Sanibel lies near the northern edge of the subtropical land and sea biomes. Consequently, the island and its surrounding waters exhibit a remarkable diversity of tropical and non-tropical plant species (Long, 1973). It is largely this diversity of natural vegetation that makes the island so hospitable to wildlife, especially the many migratory birds using the Atlantic Flyway (Hewitt, 1975). Further, warm Gulf waters have virtually eliminated seasonal temperature extremes that could limit biological productivity and development. Therefore, both fauna and flora grow and develop throughout the year.

Many of the naturally occurring, native, species of wildlife perform valuable ecological functions. For example, alligators make and maintain shallow open water ponds for their nesting that provides habitat for numerous other organisms. Other more recent arrivals or introduced animals like the armadillo, feral dogs and feral cats may adversely affect the balance of native wildlife populations by predation and competition for resources. (In recent historic times bear, deer and quail have become extinct on the island, the latter probably from predation by feral cats.)

The apparent benefits of island life are tempered by other geographical considerations. All of the low-lying island is exposed to the subtle effects of the sea as well as the drastic forces of storms. There is a limited, seasonal abundance of fresh water, with flooding wetlands, and the more drastic consequences of widespread flooding by hurricane-driven salt water.

Another constraint is the problem of space itself. Wildlife are limited first by the size of the island and second by the amount of habitat that satisfies their individual needs. Con-

Subsystem Species	Habitat		Seasonal Occurrence		Visible Populations			Feeding Behavior			Social Behavior	
	Restricted	Non-restricted	Permanent	Transient	Abundant	Common	Rare	Omnivore	Carnivore	Herbivore	Social	Solitary
Gulf Beach												
Loggerhead turtle	x			x			x		x			x
Shore birds	x		x	x	x	x	x		x		x	
Raccoon		x	x			x		x				x
Ghost crab	x		x			x		x				x
Interior Ridges												
Gopher tortoise	x		x				x			x		x
Raccoon		x	x			x		x				x
Armadillo		x	x				x		x			x
Grey Fox	x		x				x		x			x
Oppossum		x	x			x		x				x
Red-shouldered hawk		x	x			x			x			x
Lizards	x		x			x	x		x			x
Interior Wetlands												
American alligator		x	x			x		x				x
River otter		x	x			x			x		x	
Marsh rabbit		x	x			x				x		x
Anhinga		x	x			x			x		x	
Red-winged blackbird	x			x		x				x	x	
Turtles, frogs	x		x			x	x	x	x			x
Mangrove Estuary												
Wading birds		x	x	x	x	x	x	x	x		x	
Pelican	x		x			x			x		x	
Osprey		x	x			x			x			x
Raccoon		x	x			x		x				x
Mangrove water-snake	x		x				x		x			x
Ducks		x		x	x	x	x		x	x	x	

Table I - Ecological matrix of example wildlife species of four major ecological subsystems of Sanibel.

sequently, the populations of many species are delicately in balance with their limited resources. Destruction of these restricted environs can stress or exterminate populations like the gopher tortoise, the burrowing owl the mangrove water snake, or the river otter.

THE FOOD CHAIN

As part of a complex web of life, each species of wildlife represents an energy pathway through the living world. The animal kingdom must first acquire its energy from plants. Herbivorous animals perform this first step. On Sanibel this task is handled primarily by a wide variety of first order consumers: bees, ants, mosquitoes, flies, grasshoppers, butterflies, caterpillars, snails, several birds (e.g., ground dove, cardinal and ducks) and several mammals (rats, mice, and the marsh rabbit). Without doubt insects constitute the major consumer at this trophic level.

Type of Bird \ Type of Food	PLANT MATERIAL	BERRIES, FRUITS, SEEDS	INSECTS	FISH	AQUATIC INVERTEBRATES	REPTILES AND AMPHIBIANS	SMALL MAMMALS	SCAVENGERS
PASSERINES	--	20	29	-	2	-	-	3
WADERS	1	1	9	8	5	4	1	-
SHORE	2	1	13	8	15	1	2	3
DIVERS & DUCKS	4	3	8	6	9	2	1	-
RAPTORS	-	-	3	-	1	2	2	2
TOTAL	7	25	62	22	32	9	6	8

Table 2 - Food of common species of resident or seasonal birds on Sanibel Island; recorded are the number of species which feed significantly on the categories listed.

Sanibel's subtropical climate is ideal for insect reproduction and development; as exemplified by the results of Maurice Provost's mosquito studies on Sanibel. On the night of September 15, 1950, Provost captured 365,696 mosquitoes in a single trap on Sanibel; measured 45,000 mosquito eggs per square foot along the Sanibel Slough the following summer and stated that swales on Sanibel holding half-a-billion eggs to the acre were common (Provost, 1969).

These figures assume staggering ecological significance when the variety of herbivorous insects on Sanibel is considered along with the number of acres of suitable insect habitat. Many species of wildlife are dependent on mosquitoes and other herbivorous insect species. For example, Gambusia and killifish at certain times of the year feed almost entirely on the herbivorous mosquito larvae developing in shallow fresh and brackish waters. These minnows, in turn, are an essential food for larger commercial and game fish, and the many wading birds for which Sanibel is famous. The adult mosquito itself is food for spiders, toads, nighthawks, and dragonflies.

Still other herbivorous insects, such as bees, butterflies, and moths, perform valuable services to man

Species \ Status	Endangered	Threatened	Rare	Special concern
Amphibians				
Little grass frog				x
Florida cricket frog				x
Florida chorus frog				x
Reptiles				
Gopher tortoise		x		
Florida brown snake		x		
Florida ribbon snake		x		
Eastern indigo snake				x
American alligator				x
Birds				
Wood stork	x			
Brown pelican		x		
Magnificent frigate bird		x		
Southern bald eagle		x		
Osprey		x		
American oyster catcher		x		
Least tern		x		
Roseate spoonbill			x	
Mangrove cuckoo			x	
Little blue heron				x
Louisianna heron				x
Yellow crowned night heron				x
Least bittern				x
White ibis				x
Caspian tern				x
Black skimmer				x
Snowy egret				x
Great egret				x
Burrowing owl				x
Mammals				
Florida panther	x			
Round tailed muskrat				x
Sanibel Island rice rat			x	

Table 3 - Rare and endangered Florida wildlife recorded for Sanibel Island. (From Florida Environmentally Endangered Lands Plan).

(pollination of fruit and vegetable crops) and also support insectivorous populations of reptiles, amphibians, birds and mammals.

Further, the herbivorous insects, birds and mammals function as "gardeners"

I. Geographic Origins
   A. Indigenous
   B. Introduced (exotic, feral)
   C. Potential "invader" species from neighboring islands and mainland.

II. Abundance
   A. Extinct
   B. Officially endangered
   C. Formerly present on island
   D. Overabundant, to the nuisance point

III. Presence on Island: Overview or Inventory
   A. Full-time (food and nest-site-dependent)
   B. Transient (food or nest-site-dependent)
   C. Seasonal (nest site and food dependent for part of year only)

IV. Habitat Restrictions
   A. Requires more than one habitat
   B. Adapts to more than one habitat
   C. Restricted to one habitat

V. Intraspecific Interactions
   A. Territorial breeding season only
   B. Territorial, low-density
   C. Territorial, high-density
   D. Gregarious, non-territorial
   E. Strong homing instinct

VI. Interspecific Interactions
   A. Provides food source for co-habitor species
   B. Competes for food source with co-habitor species
   C. Provides "housing" for co-habitor species
   D. Competes for space with co-habitor species
   E. Preys upon co-habitor species

VII. Interactions with Man
   A. Visible
   B. Secretive
   C. Utilizes man-made food supplies
   D. Utilizes man-made habitats
   E. Food supply decreased or eliminated by man
   F. Habitat decreased or eliminated by man
   G. Adapts to disturbed habitats

Table 4 - Ecological, behavioral and human value parameters involved in the evaluation of individual species of wildlife with respect to their conservation.

MAN'S ACTIVITIES AND ENVIRONMENTS / SPECIES OF WILDLIFE	Ghost crab	Loggerhead turtle	Grey fox	Bobcat	Quail	Marsh rabbit	Rodents	Lizards	Snakes	Passerine birds	Raccoon	Armadillo	Alligator	Herons	Hawks	Least tern	Black skimmer	Burrowing owl	Gopher tortoise	Laughing gull	Great blue heron	Great egret	Little green heron	Kestrels	Cormorant	Red shoulder hawk	Anhinga	Brown pelican	Osprey	Bald eagle	Vultures	Cattle egret	River otter	Feral animals
IMPACT OF MAN-ENVIRONMENTS																																		
Loss of habitat	x	x	x	x												x	x	x	x															
Pet predation					x	x	x	x	x	x																								
Pet competition			x	x							x	x	x	x	x				x															
Introduced hazards		x	x		x	x	x	x	x	x	x	x	x															x						
"PANHANDLER" SPECIES											x		x	x																				
"COSMOPOLITAN" SPECIES							x				x	x	x							x												x	x	
"OPPORTUNISTIC" SPECIES OF MAN-ALTERED HABITATS																																		
Cleared land																x	x															x		
Golf courses																		x														x		
Yard,hedge,lawn										x											x	x										x		
Picnic areas											x									x														
Roadsides																			x												x	x		
Utility wires																							x	x	x	x								
Utility poles																				x					x	x	x	x	x	x				
Channel markers																				x							x	x						
Boat docks																				x	x						x	x						
Mosquito ditches						x							x								x	x	x										x	
Real estate lakes													x								x	x	x										x	
Canals													x								x		x					x						
Australian pines										x											x				x		x	x	x	x				
Brazilian pepper tree										x																								
SPECIES WITH POSITIVE ECONOMIC-SOCIAL VALUE																																		
Economic		x											x	x			x			x	x	x			x		x	x	x				x	
Recreational											x		x	x		x	x		x	x	x	x			x		x	x	x	x			x	
Aesthetic	x	x			x	x				x	x		x	x	x	x	x	x	x	x	x	x			x		x	x	x	x			x	
Highly visible		x				x				x	x		x	x	x	x	x			x	x	x			x	x	x	x	x		x	x		
SPECIES WITH POTENTIAL NEGATIVE ECONOMIC-SOCIAL VALUE							x		x		x		x																				x	

Table 5 - Impact-response matrix of selected wildlife to man-dominated environments of Sanibel Island.

of the native vegetation, providing fertilizer, pruning, seed dissemination and planting. (One herbivore, the gopher tortoise, is an extremely important species that will be examined as a member of the upland subsystem.)

Another set of wildlife species operates at the next trophic level as second-order consumers. These are the insectivores, carnivores, and omnivores. Again, their presence and abundance depends upon and reflects the status of herbivores on which they prey. The insectivores are well represented island-wide by predacious insects, spiders, wasps, dragonflies, frogs, toads, lizards, mammals and birds.

Many birds are obligate insectivores. Some, such as the pileated woodpecker and the common nighthawk, are selective as to type of insect prey. Others, such as the yellow throat, prairie warbler, black-and-white warbler, gray kingbird, purple martin, Carolina wren and the vireos, feed on practically any available insect within the size range they utilize.

Several mammals--shrews, moles, some rodents, and all rats--feed almost exclusively on insects. Less than a fraction of a percent of all insect species are inimical to man's interests. Numerous insect species are predators or parasites on other insects, and perform an invaluable service in control of populations.

To maintain Sanibel's interesting and unique diversity of birds and other wildlife, for human or ecological reasons, natural insect environments must be maintained.

Insect-eating fish, amphibians, reptiles, etc., support third order consumers in large part; these are the carnivores and omnivores, such as herons, egrets, terns, opossum, armadillo, and snakes.

The highest trophic level predators, are the fourth order consumers that may feed on one or more of the smaller or weaker species. For example, the red-shouldered hawk will eat herbivores (rabbit), insectivores (frogs), carnivores (snakes), or omnivores (rats and mice).

Lastly, we must consider the scavengers. Scavengers occur in every habitat. Often their activities and presence go unnoticed or at least their ecological functions go unappreciated. However, several of Sanibel's conspicuous scavengers are exceptions. The black vulture and the turkey vulture help to keep the roadways free of car kills. The ubiquitous gulls rapidly dispose of the constant and periodically large quantities of beach-cast fish, shellfish and other carcasses.

The following sections discuss important species and ecological subsystems. Together and individually these sub-systems provide wildlife habitat for a variety of important species (Table 6). Over many years these species have achieved a dynamic equilibrium with Sanibel's biological and physical resources. This section has considered a few common species whose presence and influence are island-wide. The discussion of trophic levels has emphasized the essential roles that several important species play in keeping the island's natural systems in balance.

The Beach Subsystem

The Gulf Beach Subsystem begins on the seaward side of the coastal strand, behind the primary dunes and here includes: the primary beach sand dunes, the backshore beach, the intertidal foreshore beach, the inshore breaker zone that extends into the "nearshore" waters (300 feet to the boundary of jurisdiction or city limits). The ecology of this last zone (nearshore) has been treated by Morrill and Byle (1976) and is discussed here only as it related to the wildlife ecology of the other zones.

Physically, the five zones function as a single system, a relatively narrow zone of fluid sand that continuously molds itself to the daily, seasonal and annual forces of the sea. Each zone is a product of an reflects the various degrees of wind, wave and current action affecting Sanibel's Gulf coast.

The relative harshness of this environment limits the number of species that can live here to a comparative handful of hardy, uniquely adapted plant and animal species. Some highly specialized species (i.e., ghost crabs, beach fleas, and coquinas) are permanent residents, but most, like the shorebirds, diving birds, sea turtles, and raccoons are visitors only. Over time, many species have become dependent on the beach complex in some way or another. All bury themselves in defense against the crashing waves and being tumbled up and down the beach. Here, masses of coquinas and beach fleas occur and attract flocks of dunlins, plovers, sanderlings, sandpipers and other shore birds. The agile snowy egret and Louisiana heron are often found chasing minnows between the waves.

In the near and inshore zones there are many types of phytoplankton that function as producers. These in turn are fed upon by many macrofauna that exhibit special locomotory, respiratory, and morphological adaptations that permit them to inhabit the shifting sands while filtering out their food supply. They, in turn, provide food for predaceous molluscs, rays, and the loggerhead turtle. Here too live many of the shellfish species whose shells wash ashore, and give Sanibel its great reputation for shell hunting.

In the open water are surf minnows (i.e., menhaden, anchovy, and fry), commercial and sport fishes; all are preyed upon by a variety of other fish, birds (e.g., terns, skimmers, cormorants, pelicans, osprey) and man.

In view of the historically stable nature of this zone on Sanibel (Missimer and Riggs, 1976), the greatest direct threat to wildlife is from the growing numbers of beach walkers, waders, and shell collectors.

Above the tidal foreshore zone, occurs the familiar backshore beach

Trophic Level Representatives / Reference Area (Complex)	Energy Producers (Native Plants)	1st Order Consumers (Herbivores)	2nd Order Consumers (Insectivores)	3rd Order Consumers (Omnivores)	4th Order Consumers (Dominant Carnivore)	Detrital Consumers (Scavengers)
ISLAND WIDE SYSTEM	All Vegetation	Many Herbivorous Insects and their larval stages	Spiders, Dragonflies, Frogs, Lizards, Nighthawks, Woodpeckers	Raccoon Fish Crow	Feral Dogs & Cats have replaced Bobcat, Panther and Grey Fox	Bacteria, Ants Beetles, Turkey & Black Vulture Fish Crow
GULF BEACH COMPLEX — Marine	Phytoplankton, Algae, Seagrasses	Zooplankton	Killifish, Menhaden, Clams, Cockles, Penshells	Conchs, Whelks, Rays, Loggerhead, Herons, Egrets, Pelicans	Shark	System Scavengers plus Gulls, Ghost Crab, Ants
GULF BEACH COMPLEX — Terrestrial	Sporobores, Ipomoea Bay Cedar Marsh Elder Cocoplum Sea Oats	Grasshoppers Marsh Rabbit	Tiger beetles Spiders Warblers	Raccoon Rats, Mice	Ferals	
INTERIOR RIDGE COMPLEX	Cabbage Palm Sea Grape Buttonwood Gumbo Limbo Strangler Fig Wild Lime, Cats Claw, Myrsine, Stoppers, Ernodea, Wild Coffee Cactus, Grasses	Insects & Larvae Tortoise Marsh Rabbit	System Species plus Wasps Other predaceous insects, Warblers Vireos, Quail	Indigo, Racer Rattlesnakes Raccoons Rats & Mice Armadillos Opossum	Red Shoulder Hawk Ferals	System Scavengers plus Ants and Beetles
INTERIOR WETLAND COMPLEX	Phytoplankton Duckweed Widgeon grass Chara, Cattail Sawgrass, Cordgrass, Sedges, Grasses, Myrtle Leather Fern Buttonwood Distichilis	Mosquito Larvae Snails, Grasshoppers Caterpillars Marsh Rabbit Rats	Spiders Frogs Toads Wizards Dragonflies Vireos Warblers Killifish	Herons, Egrets Rail, Coot, Snakes Raccoon	Red shoulder Hawk Alligator Otter	System Scavengers plus Crabs
MANGROVE ESTUARINE COMPLEX	Phytoplankton Algae Sesuvium Philoxerus Batis Mangroves	Mosquito Larvae Insects Ducks Mullet	Spiders, Anol Warblers, Cuckoo Woodpeckers Killifish	Herons Egrets Spoonbill Ducks Coots Raccoon Gamefish	Cormorant Pelican Osprey Eagle Alligator	System Scavengers plus Gulls and Crabs

Table 6 - Summary of important animals in the food-webs of the ecological subsystems of Sanibel Island.

zone which extends to the base of the primary dune. The lower portion is literally devoid of resident animal life and the upper portion boasts few permanent residents like the ghost crab and a few insects. Its physical presence is perhaps its most valuable feature. The offshore bar and the back beach slope function together as the island's first defense against the sea. Here, storm waves lose much of their erosive energy on the gradual incline. Thus, the backshore beach protects the interior habitats from destruction.

It is well known that the loggerhead sea turtles (Caretta caretta) return to Sanibel Island each summer to lay their eggs in shallow sand nests on the upper portion of the backbeach. The majority of the nesting sites between 1971 and 1975 have occurred on the more isolated, undeveloped beaches west of Tarpon Bay Road to Blind Pass. Annual reports of Caretta Research, Inc., indicate that lights from condominiums and motels, and people with flashlights in the more developed areas east of Tarpon Bay Road disturb the nesting turtles and may cause "false crawls". Turtle nesting is declining as evidenced by a decrease from 12 nests in 1970 to 5 nests in 1975 at one nesting area, Turner Beach near Blind Pass (designated as the Turner Beach Loggerhead Turtle Sanctuary by the Lee County Board of Commissioners in 1969). In June of 1974 a tropical storm altered the beach profile and caused a number of Australian pines to fall into the Gulf waters of the beach. That fallen trees on the beach interfere with nesting activities appears obvious. Less obvious perhaps is the slope of the foreshore and width of the beach between the high tide line and the beach grass zone. East of Tarpon Bay, the intensive beachfront development complemented by a very low foreshore profile may discourage successful nesting. West of Tarpon Bay Road, the 1975 nesting census indicates certain sections of the beach have more nests than others and that more turtles nested in 1975 than 1970 even though the human population and beach activity had increased over the five year period. Accordingly, attention should be given to study of the factors involved in beach site selection by nesting turtles, particularly if sections of the beach are to be designated as turtle nesting sanctuaries.

A second aspect of turtle nesting success involves predation by humans, raccoons and ghost crabs. LeBuff (1969) reported that of 168 nests on Sanibel and Captiva Islands, humans excavated 15, raccoons dug up 6, ghost crabs tunneled into 24, storm tides destroyed 16, and erosion destroyed 4. Of the estimated 6,215 hatchlings that may have reached the Gulf from the surviving nests, perhaps only 15 would survive to breed. Prior to 1964 the raccoon population became rather large before it was decimated by a virus. Reports of families of raccoons eating turtle eggs as they were laid occur in the literature. With the reduction in the raccoon population which also preyed on ghost crabs, the ghost crab population increased with an increase of predation of turtle nests by the tunneling crabs.

Preservation of turtle nesting grounds is needed also because the loggerhead is a key figure throughout the marine ecosystem--both as an important predator (of clams, conches, crabs and the dangerous Portuguese man-of-war jellyfish) and as prey (eggs eaten by ghost crabs and raccoons; young by marine birds and fish; adults by sharks and man). Their role as a reliable transport mechanism within their extensive migratory range is absolutely unique whereby as many as 100 different species of marine life have been found on turtles' backs.

Protection of the backshore beach nesting habitat is critical, and should take precedence over human use of this zone during the nesting season if the turtles are to survive.

Immediately behind the backshore beach, lie the primary beach sand ridges (dunes). Here, salt-tolerant vegetation --sea oats, railroad vine and purslanes-- trap the wind-blown sand. Physically, the primary dune serves as a beach sand reservoir, releasing sand back to the beach during severe storms.

Historically, some of the shorebirds --snowy plover, Wilson's plover, willett-- nested and roosted in this zone, but construction, foot traffic, picnicking, sea oat seed collecting by humans and dense strands of Australian pines have seriously degraded wildlife habitat on the primary dunes. In some places the dunes have been completely destroyed and built upon.

Adherence to the coastal construction set-back line, construction of dune crosswalks, and dune restoration where necessary would be a valuable first step in restoring the natural function of the primary dune system.

In summary, the Gulf Beach complex is far more than just a barren strip of sand. The complex was historically an important wildlife habitat and a reservoir for beach sand, and is the front line of protection for the island during storms.

The integrity of this subsystem depends on the maintenance of each of its interrelated and interdependent zones. Each of these zones requires special and equal attention to insure that the entire complex is permitted to function as a system.

Uplands Subsystem

The interior ridge complex is made up of those lands in the island's interior not inundated by seasonal high water. The lands were formed as a series of beach ridges in parallel sub-sets of between seven and twelve (Missimer, 1973). Over most of the island, these ridges reach an elevation of three to six feet above sea level and are covered with a dense growth of sub-tropical trees and shrubs.

The habitats within this subsystem vary from desert-like conditions on the higher ridges in the western part of the island to dense hammocks of West Indian vegetation scattered throughout the island at lower elevations.

Most of the interior ridge complex is heavily vegetated. Accordingly, wildlife have adapted to these conditions. Woodpeckers frequent insect-invaded trees seeking insect larvae and commonly create hollows in a cabbage palm or strangler fig for their nests. In addition to providing a source of food and a place for nesting or perching, the vegetation of these ridges provides important cover for species that must be wary of predators. The practice of clearing understory vegetation from around trees in developments reduces habitat and protective cover. Songbirds, and other wildlife species generally considered attractive in the residential environment, are among the first to be adversely affected by this practice.

Much of the wildlife of the interior ridges is wide-ranging and can be found in the other subsystems at various times, but the upland species are those that have adapted life styles tying them in some manner to the upland habitat. Burrowing animals, for example, may range over the island, but must construct their burrows on the ridge to stay above the water table.

The most prominent burrowing animal of the interior ridge complex is the gopher tortoise. This reptile grazes on herbaceous plants of the ridges and associated swales. It is particularly important to the ridge wildlife complex because its burrows provide refuge for a variety of species, including reptiles, amphibians, raccoon, opossum, and a host of invertebrates (Campbell, 1975).

Snakes are relatively abundant in the upland areas, though seldom seen. Species like the endangered indigo snake which feeds on rodents, may be observed in residential areas seeking small mammals commonly associated with human habitations. Bird feeders generally attract rodents that occupy the interior ridges.

Wildlife forms that have adapted particularly to the drier open ridges, like the six-lined racerunner lizard, are being presented with an expanding habitat. Development practices that require removal of vegetation reduce moisture retention of the shallow soil, creating dry (xeric) conditions on the higher ridges. The racerunner population has increased accordingly.

The introduction and rampant growth of exotic tree species that outcompete native vegetation will ultimately take its toll on the wildlife of the ridges. Where established, Casaurina and Schinus crowd out native plants and prevent natural succession (Alexander, 1975). While there is some wildlife utilization of the invading trees, unless their destructive spread is brought under control, the diversity of wildlife species on the ridges and in other affected habitats will certainly decline.

Introductions of non-native species are placing unnatural pressures on other wildlife. Breeding populations of feral cats are well established on the island. The feral cat is a deadly hunter feeding on reptiles, birds, and mammals. Ground nesting birds on the interior ridges are particularly vulnerable.

Most of the future development of Sanibel will occur in the interior ridges of the islands because the least alteration of the ecosystem is required in this subsystem to provide suitable residences. The alteration of habitat will displace wildlife and undoubtedly reduce their numbers.

Interior Wetlands Subsystem

Of the wildlife species that occur on Sanibel, most can be found in the habitat provided by the interior wetlands complex (Campbell, 1975; Alexander, 1975). It is in the low-lying interior of the island that fresh water is collected in seasonally inundated marshes and perennial channels and ponds. This hydrologic system, as reported by Missimer (1976), is unusual for a barrier island and accounts for much of the wildlife diversity found on Sanibel.

The interior wetlands complex of Sanibel sets it apart from all other barrier islands. Yet, as the most intricate and most fragile complex of the island's natural system, it is also the most vulnerable to insenstive development. Maintenance of the environmental integrity of the interior wetlands complex that supports a healthy wildlife population means a healthful environment for people.

The interior wetlands provide some of the most productive and valuable wildlife habitat on the island. As reported by Hewitt (1975) and Campbell (1975), of a total of 84 species of reptiles, amphibians, and mammals found on the island some 35 species and subspecies are dependent on the interior wetland habitats. Almost 300 species of birds have been recorded on Sanibel over the years, many of these species occur only occasionally, however, there are 16 important species that are common in the fresh-to-brackish water habitat of the interior wetlands.

The existing interior wetlands must be protected and improved if they are to continue to support present wildlife population levels. Increasing salinity, dredging, and introduced pesticides all appear to be lowering populations of reptiles and amphibians. Excavations that allow salt water intrusion is probably contributing to this decline. Raising the water table and increasing the storage capacity of the water-table aquifer will lower this salinity extreme and probably boost reptile and amphibian populations. (Campbell, 1975; Tabb, 1975.)

The chief factors influencing bird populations appear to be vegetation and food supply. Presumably if historic bird habitats are to be preserved and population numbers restored, exotic plants will have to be controlled and "natural" wetland vegetation re-established. If the wetlands are to remain viable with ample forage fish populations, water levels must be high and salinity low. However, the present mix of birds, mammals, reptiles reptiles, and amphibians shows an increase in number of species able to tolerate people, developed land, and saline water conditions (Campbell, 1975).

CONDITION OF WETLANDS

The interior wetlands complex includes about 1850 acres of marsh in the center of the island (remaining of an original 3000-4000 acres), connected by the Sanibel River and a network of tributary canals created for mosquito control purposes. Additionally, a number of borrow pits in the interior have created fresh and brackish water ponds that, for the purposes of wildlife assessment, are included among the habitats discussed here.

In its earlier unaltered state heavy summer rains inundated the island's interior lowlands, creating vast areas of open water and marsh. Surplus water was slow to drain away, but when the water in the interior was high enough to break through the beach front sand ridge, so much water poured through the ridge into the ocean that the interior would remain relatively dry through the winter to the next summer's rains.

During the annual dry period (winter) wildlife populations were at their lowest in the island interior, but increased dramatically as the next rainy season brough water back into the marshes.

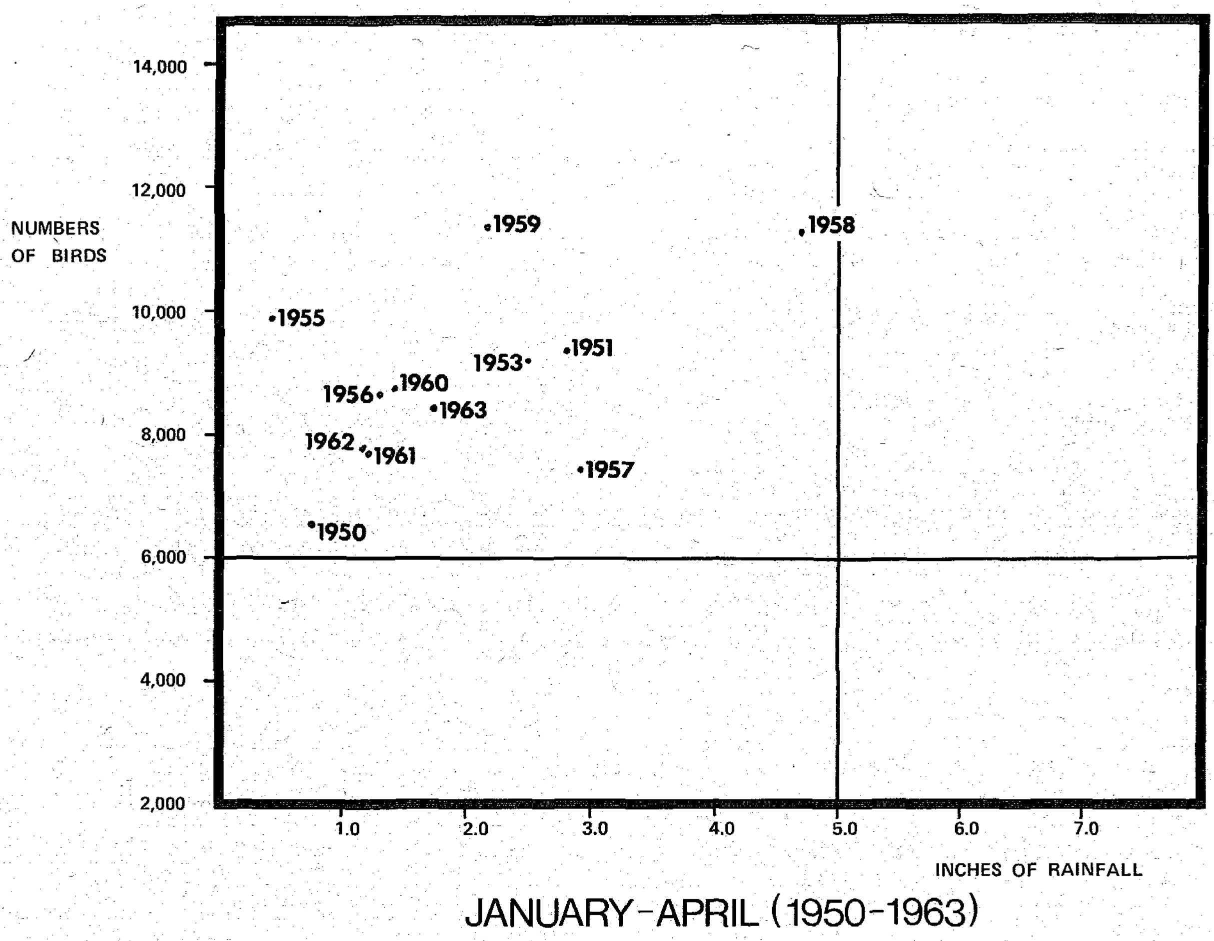

Fig. I - Estimated numbers of birds occupying the Bailey Tract of the J.N. "Ding" Darling Wildlife Refuge (as estimated by the U.S. Fish and Wildlife Service refuge staff) and total rainfall (from local rain gauge).

Mosquito populations provided a noticeable indicator of biological production when seasonal rains re-flooded the mangroves. Salt marsh mosquito egg densities along the Sanibel Slough were measured in 1950 at 45,000 per square foot or two billion to the acre (Provost, 1969). Channelization of the Sanibel River was completed in 1960. Control structures at the drainage outlets were constructed to maintain water in the wetlands through the dry season. These modifications greatly reduced mosquito production and reshaped the rest of the interior wetlands wildlife populations.

Wildlife observations and water bird counts conducted annually by the U.S. Fish and Wildlife Service in the interior wetlands indicate a positive relationship between wildlife populations and water levels. As shown in Figure 1, the numbers of birds in annual counts from 1949 through 1973 were found to fluctuate directly with recorded rainfall (Shea, 1974). Early management efforts in the interior wetlands to maintain higher water levels in the marsh increased water fowl and wading bird activity, attracted greater numbers of colonial nesting birds, and caused a noticeable increase in alligators, otters and other wildlife (Shea, 1974).

These increased populations are attributed to improved habitat and increased food supply created by the maintenance of a higher water table. The mosquito larvae-eating fish, for example, could be sustained in greater numbers through the dry season. Moreover, the additional fish population supported greater numbers of third order consumers, such as, herons, egrets and anhinga. As the base of the food chain broadened diversity and numbers of wildlife increased accordingly.

ALLIGATORS

Of all the higher order consumers, the creature most affected by modifications of the interior wetlands is the American alligator. Before channelization of the Sanibel River, the major source of fresh water available to wildlife during drought periods was in holes excavated to the water table by the alligator. These alligator holes sustained minimal wildlife populations through the dry season. The creation of permanent water in the Sanibel River provided more habitat during dry periods, and maintenance of higher water levels reduced the need for alligator holes.

The alligator as well as other wildlife responded to the expanded open water habitat by an increase in its population. Borrow pits dredged for real estate development in the interior wetlands created additional alligator habitat. However, encroachment of such developments into the wetlands has contributed to the lowering of water levels, degraded water quality, and the siting of residential areas of the island in the midst of a major portion of the alligator population.

VEGETATION

Vegetation of the interior wetlands subsystem provides food, cover, and nesting for the wildlife population. Herons, egrets and anhingas nest in branches of trees overhanging the Sanibel River. Rails, gallinules, and bitterns utilize cattails for cover and nesting. Seeds and fruit of various plants provide food for raccoons, rodents and songbirds. Growth of food plants in the interior wetlands is often stimulated by fires in the *Spartina* marshes of Sanibel's interior wetlands. These fires were once common and distinct increases in wildlife use were noted in the burned area following fires.

Alterations of the vegetation regime of the interior wetlands can adversely affect wildlife populations. The invasion of the exotic trees *Schinus*, *Melaleuca*, and *Casuarina* represent a major threat. These trees generally invade where there has been an elevation change or lowering of the water table. Their rapid growth, crowding out native vegetation to which the wildlife is adapted, precludes natural succession and threatens biological diversity.

The lowering of the water table on Sanibel has also permitted the intrusion of salt water. This provides a direct threat to most wildlife of the interior wetlands complex. Several amphibians and reptiles are particularly vulnerable to increasing salinities and may be declining in numbers as a result of the intruding salt water (Campbell, 1975).

Mangrove Subsystem

The mangrove subsystem is the transitional habitat that separates the land from estuarine waters. The mangrove-estuarine complex includes mangrove swamps, oyster bars, shallow embayments, the impounded tidal and salt flat area in the "Ding" Darling Wildlife Refuge, the tidal flats along the northern side of Sanibel, Tarpon Bay, the mangrove-fringed bayous of the Blind Pass area, and the vegetated man-made canals. This complex consists of about 5,400 acres, nearly one half the total area of the island. The major portion of this subsystem is in the "Ding" Darling Refuge.

The mangrove subsystem now comprises about 2,800 acres of an original historical inventory of more than 3,200 acres. More than 2,000 acres of mangrove swamp is in the refuge. Other major mangrove swamps are at Wulfert Point (416 acres) and in the vicinity of Dixie Beach Boulevard--Woodring Point (339) acres. Although this complex is semi-isolated from the uplands and interior wetlands of the island by dykes and roads, mosquito control, drainage, and overflow ditches and canals provide arterial connections (Morrill and Byle, 1976).

According to Tabb et al, (1976): "The role of red mangrove communities in estuarine food chains is dependent to a large extent on their relationship to tidal range and freshwater flow. These communities which are situated within the effective intertidal range, or which are in close contact with streams or freshwater sheet flow systems, are effective contributors of debris and detrital material to adjacent estuarine waters. Fallen red mangrove leaves, unestablished seedlings, and probably bark, twigs, and root tissue, are invaded by a succession of microorganisms that assist in tissue decomposition and also produce a net increase in nitrogen content. The resultant particulate material, with its associated microbiota, is an important food source for primary consumer organisms composed of a few species but large populations. These, in turn, are the prey of several levels of secondary consumers (lower, middle, and higher carnivores). Among the primary consumers are commercially important species such as pink shrimp and striped mullet. The majority of the sport fish species, such as tarpon, spotted sea trout, red drum, and snook, occupy the middle and higher carnivore levels."

Further, "Black mangroves have been the subject of less intensive investigation. Again, their role may be determined by their geographic position in a coastal system. Black mangrove communities which are within the range of regular tides probably play a similar role to red mangroves with which they are closely associated. Black mangroves at slightly higher elevations seem to be an integral part of the mosquito-killifish food chain. In fact, they and associated plants probably produce the major part of the detritus which fuels this chain. By this pathway they presumably contribute to adjacent estuarine waters, provided that their function is not impeded by larvicide spraying, ditching, or impounding."

In relation to aquatic fauna, Tabb et al (1976) report, "Forage fishes including *Cyprinodon variegatus*, *Fundulus confluentus*, and *Poecilia latipinna* will dominate the oxygen poor areas of the mangrove system. *Cyprinodon* is perhaps the most salt tolerant species, surviving from 0.120 ppt and breeding from 1-80 ppt. This species is generally excluded from areas where primarily freshwater fishes are abundant and from bays where salinity, clarity and mixing permit dense growth of sea grasses. All three species are euryhaline and, in addition, are capable of using the surface film of water for respiration. Even if the area were to dry out, *Fundulus confluentus* can defer hatching of eggs and the eggs can withstand relatively long periods of exposure to dry conditions. These small fishes, together with fiddler crabs, form the major diet of herons, ibis, pelicans, roseate spoonbills, and mammals such as raccoons. Among the larger fishes the tarpon, *Megalops atlantica*, an obligate air breather and euryhaline form, and the ladyfish, *Elops saurus*, are admirably suited to this environment. Mullet, *Mugil curema* and *M. cephalus*, can also be found here utilizing the surface film for feeding and respiration. Invertebrates will be dominated by the fiddler crabs, *Uca* spp., mangrove crab, *Aratus pisonia*, coffee snail, *Melampus coffeus*, and littorinids, *Littorina angulifera*, all of which depend on air for breathing."

Tabb et al (1976) continue, "Wherever waters lead to the bay one can expect to see mojarras, snappers, snook, tarpon, needlefish and barracuda. The creek which drains a set of mosquito ditches between The Dunes tract and San Carlos Bay has been an especially valuable tarpon nursery system. As one proceeds from the least flushed inner bays toward the middle and outer bays, tidal action becomes more significant, salinities are moderated by seawater, and oxygen is added via tidal mixing. A larger variety of estuarine fishes, including mojarra, *Eucinostomus* spp.; silversides, *Menidia* and *Membras*; sea trout, *Cynocion nebulosus*; drum, *Sciaenops ocellata*; pinfish, *Lagodon rhomboides*; etc., are found and eventually the marine complement of fishes are encountered in the outer bays and tidal passes."

BIRDS

Whether they feed in the open waters, the edges or interiors of the mangroves most of the wildlife of the mangrove subsystem depend on fish, crabs, shrimp, and molluscs for food. Others, passerine birds and woodpeckers in particular, feed on insects and spiders. The seasonally present plant-eating ducks feed on widgeon grass, *Ruppia maritima*, in the refuge impoundment.

Table 6 shows that the major wading birds eat a variety of animals in the food web. Of the several species of birds listed in this table, the details of the feeding and behavioral ecology are known only for the roseate spoonbill (Allen, 1942) and the white ibis (Kushlan, 1974). Nevertheless, stomach content analyses of wading birds show that top minnows and killifish are the major food component in other areas of South Florida. If this is true for the Sanibel populations of these wading birds, then the numbers of wading birds seen feeding in the mangrove embayments, around the tidal inlets, and on the Sanibel Shoals could fluctuate with the abundance of top feeding minnows, killifish, scaled sardines, and bay anchovy. The foods of these fish in turn are, to a large degree, flood water mosquito and chironomid larvae, amphipods, and other microfauna (Odum, 1971) which are sensitive to pesticides and larvacides.

Similarly, the planktonic larvae of crabs, shrimp, molluscs, and marine worms in the mangrove embayments are adversely affected by chemical mosquito controls. The adults of these invertebrates constitute a second major food source of wading birds (Table 6) and several species of ducks. Finally, diving ducks, pelicans, cormorants, gulls, terns, skimmers and the osprey represent second and third order consumers or predators in the zooplankton-mosquito larvae-fish food webs.

Data from the "Ding" Darling Refuge Annual Reports for 1963, 1967, 1974-75, and the 1972 and 1974 Audubon Christmas Bird Count of Sanibel-Captiva (Table 7) suggest that the wintering populations of aquatic birds of the mangrove-estuarine complex and the Gulf beaches of Sanibel are declining. In particular, there is an apparent decline in the number of white ibis, brown pelicans, cormorants, gulls, terns, and shore birds. We do not know whether this trend is due to human developmental activities on Sanibel resulting in a decreasing food supply, or the loss of breeding habitats elsewhere, or to inadequate bird census data. However, a thorough analysis of refuge bird records and the Audubon bird counts for Sanibel and other nearby bird count areas where the same species of birds occur could reveal whether the apparent decline in numbers of birds is a regional or local phenomenon. If such an analysis showed that the decline for certain species is local and not regional, appropriate management programs are in order.

The principal feeding areas of the wading birds of Sanibel are

	Estimated Peak Populations Sanibel Refuge Sept. - Dec.		Audubon Christmas Bird Counts	
	1963	1967	1972	1974
Brown Pelican	1,500	230	396	338
Double Breasted Cormorant	2,300	517	760	282
Anhinga	60	65	72	61
Great Blue Heron	350	41	39	51
Little Blue Heron	1,200	600	170	62
Louisiana Heron	500	700	124	64
Great Egret	360	180	80	65
Snowy Egret	800	600	157	209
Cattle Egret	250	60	135	69
White Ibis	4,000	800	365	440
Wood Ibis	110	65	23	44
Roseate Spoonbill	75	-	4	
Gulls	6,000	-	1,220	2,008
Terns & Black Skimmers	6,000	-	773	870
Shore Birds	7,500	-	1,749	2,492
Ducks & Coots	3,700	5,100	921	1,202

Table 7 - Estimates of seasonal peak populations of water birds on Sanibel Island. Compiled from annual reports of J.N. "Ding" Darling Wildlife Refuge.

the tidal flats of Sanibel Shoals and Tarpon Bay, the tidal inlets connecting the shoals area and the mangrove embayments of the "Ding" Darling Refuge, the tidal flats of the refuge and its impounded area, and the edges of the mangrove islands and swamps. Some species are social feeders and some solitary feeders. The seasonally present fish-eating ducks feed in the open embayments of the refuge, Tarpon Bay, and adjoining waters of Pine Island Sound. In years when the salinity in impounded areas of the refuge is low, weed-eating ducks congregate there; when the salinity is high these ducks feed primarily in the Sanibel River and fresh water sloughs. In addition to Tarpon Bay and other open waters around Sanibel a prime fishing area for the brown pelican and double crested cormorant is in the vicinity of Blind Pass where large numbers of fish occur in waters of the pass and the adjoining bayous.

In this area the larger water birds--brown pelican, cormorant, herons, and egrets--may be seen resting in Australian pines along the bayous. The osprey has already adapted to nesting on certain utility poles on the island in lieu of suitable tall dead trees. North of Sanibel in Sarasota Bay, colonies of snowy and great egrets are beginning to nest in Australian pines on a spoil island. In view of this, Silver Key and shores of Old Blind Pass might possibly evolve into a small rookery.

This raises the question as to why there are no major breeding rookeries of pelicans, cormorants, and wading birds in the mangrove-estuarine complex on Sanibel Island, even though many of these species occur throughout the year on the island. Whatever the reason, the island's mangrove-estuarine complex serves as a refuge and feeding area for numerous adult and juvenile aquatic birds in the same way that it does for juvenile marine fish and shellfish. Thus, while natural nesting colonies of some birds (i.e. pelicans and cormorants) do not presently exist on Sanibel, conservation programs should focus on maintaining and improving feeding habitats and the foods therein.

It is of considerable interest that certain beach nesting birds (i.e. least tern and black skimmer) that did nest on the undeveloped beaches recently nested on the man-made open sandy uplands of The Dunes development east of Dixie Beach Boulevard in 1975. Portions of such areas created in major development projects might be set aside as open space and managed for the breeding of shore birds (Sots and Parnell, 1975). Such a program would conform with both conservation and development interests. Accordingly, the nesting areas on The Dunes demand immediate ecological analyses.

Because it nests on utility poles and is a conspicuous and threatened species, the osprey's environmental requirements are the object of concern throughout the United States. In Southwest Florida and on Sanibel Island in particular its numbers are increasing. The osprey nest census records of the "Ding" Darling Refuge show that the number of active osprey nests (breeding pairs) increased from 8 in 1975 to 19 in 1976. Most of the active and inactive nest sites for these two years were located in tall mangrove trees within the refuge proper. Thus, continued human development of the island will probably not directly affect the osprey population nesting in the refuge, but may show an effect at the nesting sites in the dead mangroves east of Dixie Beach Boulevard.

Because the endangered osprey is relatively tolerant of humans and their activities (at least during the breeding season) and its highly visible nest sites are frequently used year after year, it is becoming a popular tourist site comparable to that of Sanibel's alligators or roseate spoonbills.

Among the relatively inconspicuous or shy wildlife restricted to the mangrove swamps are the resident mangrove water snake which feeds primarily on fish, and the rare mangrove (Maynard's) cuckoo whose diet is almost exclusively caterpillars of various sorts. A number of migratory insectivorous songbirds (i.e. warblers and black-whiskered vireos) and several species of woodpeckers also forage in the mangrove swamps. Of the insectivorous species of amphibians and reptiles, the Florida cricket frog, squirrel tree frog, and green anole are common in the mangroves. Again, we have a group of wildlife whose presence on the island and in the mangroves depends on a food source adversely affected by chemical mosquito control programs.

Several species of wildlife such as the raccoon, opossum, alligator, otter and other mammals retreat or migrate to the mangrove swamps when their food or environmental space is stressed or limited in other habitats on the island. In one sense the mangrove swamps are potentially an open habitat or community. As the environmental space of other ecological zones on the island is altered and dominated by man's activities, additional numbers of wildlife may be forced to emigrate into that 50 percent of the island dominated by the mangrove community.

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APPENDIX 5

APPENDIX 5

ESTUARINE ECOLOGY

by John B. Morrill and William K. Byle, Jr.

This report represents the combined findings of a literature search on the marine ecology of Sanibel and a two-week field study of Sanibel's marine ecosystem. The literature search encompasses a wide variety of published and unpublished reports collected from research libraries in Miami, Ft. Myers, Sanibel, Sarasota and St. Petersburg, Florida; from private libraries and collections, and from engineering firms. Additional background and historical information was considered by interviewing selected residents.

Field studies were conducted the second and third weeks of June 1975 to provide firsthand visual observations of the major physical and biological resources. Daytime studies were conducted from a small boat used to map tidal patterns, assess water quality, record depth and sediment characteristics, map benthic flora, inspect natural and man-made features, observe bird populations, etc. Walking, wading and snorkeling (freestyle and towed behind a boat) were employed for closer analysis, sampling and collecting. Still further analysis was made using old and new one to three-hundred scale County aerials, other aerial photographs and maps, and by studying color and infrared 35 millimeter slides taken for the project. One night trip was conducted with a local bait fisherman in order to observe what species were using the Sanibel Shoals at night.

This report is a systematic presentation of the data and recommendations requested of this team by the Conservation Foundation.

The Physical Environment

BIOCLIMATE

Sanibel Island falls within the tropical savanna climatological zone delineated by Hela (1952). The Sanibel Island Marine Ecosystem (S.I.M.E.) experiences a comparatively mild climate having two significantly distinct seasons: a warm, rainy summer from May through October and a cool, dry winter from November through April (Figures 1 and 2 and Tables 1, 2 and 3).

In the winter, waters are significantly (16°F) cooler than summer waters (See University System of Florida, 1973) and are characterized by higher salinities, lower nutrient levels and increased clarity (reduced turbidity). Biologically, respiration, detrital decomposition and biological oxygen demand decrease with a subsequent decrease in turbidity and primary productivity.

The warmer summer waters (78-81°F) are mixed with the seasonal runoff which produces lower salinities, higher nutrient levels and decreased clarity (increased turbidity). Biological respiration, detrital decomposition and biological

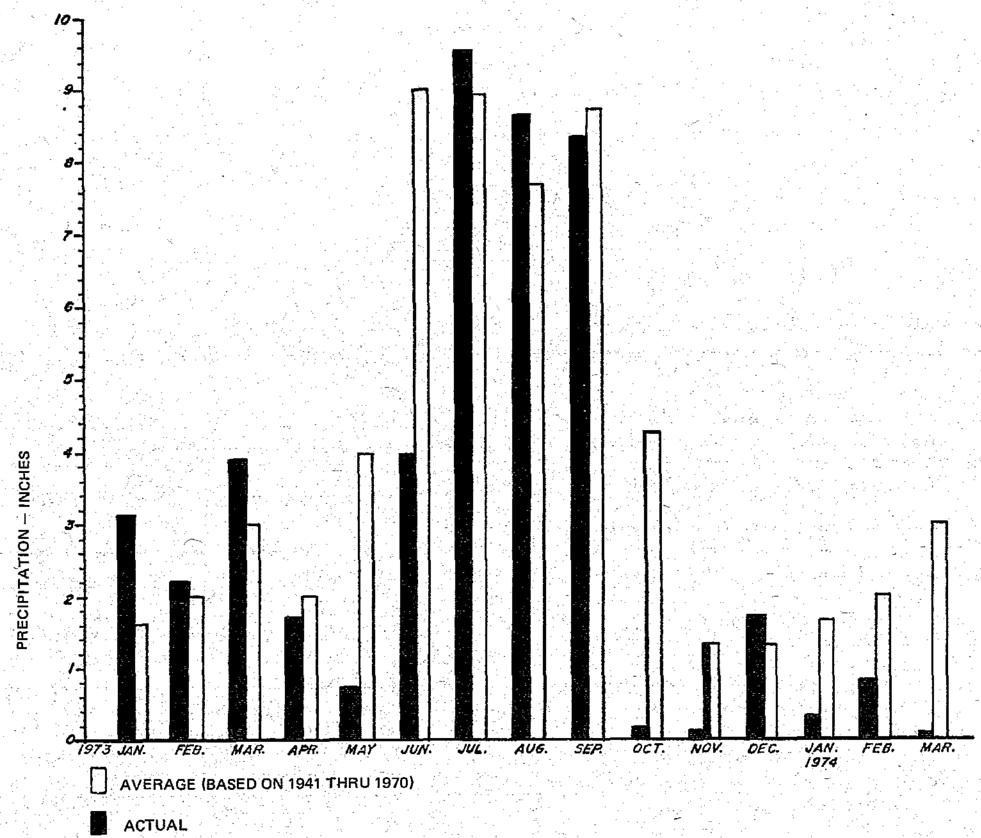


Fig. I - Average and actual monthly precipitation from weather observations Page Field, Ft. Myers, Florida. (After Duane Hall and Assocs., 1974)

oxygen demand increase with a subsequent increase in turbidity and primary productivity.

Directly and indirectly, the seasonal rainfall and fresh water runoff induce rapid chemical and physical fluctuations in the character of the estuarine waters. Periodic tropical storms (hurricanes) may affect the marine waters much as they affect the associated uplands, temporarily changing both the chemical and physical character of the marine habitat. Overall, however, the bioclimate of the S.I.M.E. appears to be significantly more stable than similar habitats, perhaps because of greater oceanic influence. This important ecological consideration accounts for its unique ecological character and resources.

CIRCULATION

As one of the most prominent barrier islands on the Florida coast and lying both at the south end of Pine Island Sound and Matlacha Pass, across from the mouth of the Caloosahatchee River, the S.I.M.E. is subjected to a complex combination of circulatory mechanisms. It is well known that circulation is the net product of many factors other than geographical location and tides, i.e., adjacent land forms, prevailing winds, rainfall and runoff, temperatures and bathymetry.

The following is a discussion of only those mechanisms observed or known to play an essential role in providing the basic character of Sanibel's marine ecosystem and which directly relate to the planning and welfare of Sanibel's residents and visitors.

Littoral Currents: The littoral or longshore currents are those which move parallel to the shore along the beaches of Sanibel's Gulf Coast. While they may move in either direction, their net effect is expressed in a predominantly southerly drift of sediments which is readily observed in reviewing the evolution of Blind Pass (Figure 3) that presently separates Sanibel Island from Captiva Island to the northwest.

This current is largely responsible for many of the physical and biological characteristics of the Gulf shore and offshore environment. Here we are concerned with three aspects of the system:

(a) Physically, these currents account for the structure of the beach itself, a problem that is being considered by another phase of this project and by the beach-erosion association. Ecologically, this phenomenon is important since it also maintains the substrate composition and water quality necessary for the characteristic marine species of this habitat (sand fleas, coquinas, sand dollars, etc. and their predators). Historically, these currents have created the physical environment suitable for the nesting of the now threatened sea turtles.

(b) Biologically, the littoral current maintains many of the marine adult populations via the transport of their planktonic larval forms from along the upper and lower Florida coastlines and by carrying nutrients to these species once they establish residence.

(c) In a negative sense, the littoral current is capable of rapidly dispersing diseases and pollutants to the marine and human populations using the beaches. The opportunity for this to happen (if not already happening) was observed at the west end of the island where visually polluted canal and bayou waters are flushed out Blind Pass and then along the public beaches of Turner Beach and Bowman's Beach. The potential for this to become a more serious problem is proportional to the continuous growth and development of the Blind Pass areas of Sanibel and Captiva. A similar situation exists at the east end of Sanibel where non-point sewage and pollutant discharges from Tarpon Bay to the Lighthouse have tidal access to the public beaches.

The "outfall" from the City's Water Treatment Plant empties into the littoral beach current some 600 feet offshore near the south end of Rabbit Road. Whatever (if any) impact this may have on the local marine biota should be resolved before additional outfalls of this type are required.

Station	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
21, Chino Isl.	22.2	16.3	22.1	25.6	30.3	28.8	31.1	32.9	32.3	28.0	27.5	32.7
22 St. James City	22.2	16.9	22.1	26.9	29.7	29.3	30.0	28.8	32.1	25.6	28.9	32.7
23 San Carlos Bay	16.9	11.5	21.5	28.1	27.6	24.8	28.0	30.0	31.0	17.4	30.2	32.7
Redfish Pass Rainfall Record Jun 1968 - May 1969 (From Byle)												
	14.35	10.20	8.81	4.43	6.0	2.50	0.01	0.70	1.60	4.53	0.70	2.3
Averaged Monthly Air and Water Temperatures (^oC) from Charlotte Harbor Area, June 1968 to May 1969 (From Wang and Raney, 1971)												
Air Temperature	28.4	29.8	29.6	28.4	25.5	20.0	20.5	18.7	17.5	19.3	25.2	28.1
Water Temperature	29.1	30.9	31.0	29.5	25.8	20.8	18.1	17.8	17.3	20.2	24.4	27.4

Table I - Salinities from intracoastal waterway. June 1968-May 1969. (From Wang and Raney, 1971). See Fig. 2 for station locations.

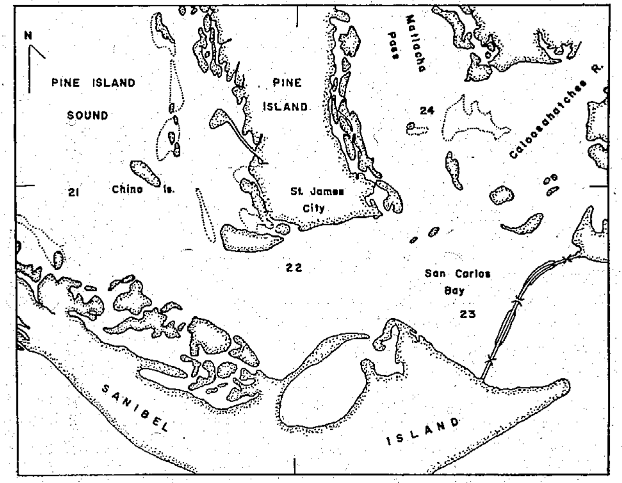


Fig. 2 - Salinity-temperature stations of Wang and Raney (1971) in lower Pine Island Sound and Matlacha Pass.

Tidal Currents play a major role in shaping many aspects of the estuarine environment on the bay side of Sanibel, but have a lesser effect on the Gulf side. Tides are usually the dominant force in the circulation of Florida's estuaries. Their circulation capacity is largely a function of the estuary's configuration, depths and proximity to the sea or major tidal inlets.

Sanibel's tides are a mixture of diurnal (one high and one low per day) and semi-diurnal (two highs and two lows a day). The diurnal character dominates during spring tides, while the semi-diurnal character occurs during neap tide periods. The mean tidal range in the Gulf is 1.8 feet and the spring range is 2.4 feet (Coastal Engineering Lab., 1959).

It is ecologically significant that the seasonally heavy rainfall and runoff periods and hurricane season coincide with the seasonally high spring tides of summer and fall. Provost (1974) explains: "We find high marsh and upland mangrove flooding starting in June and persisting through November for about nine years in a row and then lessening dramatically and lasting only through the summer for about nine years." Therefore, sections of these "higher" areas may not be flooded several months of the year (Figure 4). At the same time the mean sea level and mean high water along this section of Florida have risen nearly six inches since 1929 (Figure 5) resulting in continuous, but subtle historic changes in current, sedimentary and floral and faunal patterns as well as changes in position and definition of the Mean High Water Line.

As a barrier island, most of Sanibel's estuarine complex historically enjoyed the maximum effects of the Gulf's tidal ranges and intensities, a situation that simultaneously promoted optimal circulation,

	Development	Estimated Year of Appearance
1.	Caloosahatchee River Canal	1884
2.	Caloosahatchee River Channelization and locks	1930
3.	Sanibel Estates Canals and diversion of Sanibel River discharge	1950?
4.	Castaway Estates dead end canal	1958
5.	Lighthouse Point Development Canal	1960?
6.	Island Mosquito Ditching Program and Diversion of Sanibel River into Tarpon Bay	1960
7.	Dixie Beach Boulevard diked road	1960?
8.	Intracoastal Waterway channelization	1962
9.	San Carlos Bay spoil island Causeway	1963
10.	Sanibel Isles Development canal system	1963
11.	"Ding" Darling Wildlife Refuge Impoundment	1966
12.	Caloosa Shores Waterfront Canal System	1968?
13.	Del Sega Development Canal System	1969 - 1972
14.	Shell Harbor Development Canal System	1970
15.	Canaled Development, Southwest Shore, Tarpon Bay	1971 - 1972
16.	Sanibel Harbor Development Canal	1972
17.	Gumbo Limbo Development Tidal Canal	1973 - 1974
18.	Island Water Association water treatment plant outfall	1973
19.	The Dunes Development	1974
20.	Permanent closure of tide control gates at east end of Sanibel River	1974
21.	Moonlight Bay Development Wulfert Point	1970 Proposed
22.	Silver Key Proposed Bulkhead line	1970 Proposed
23.	Nationwide Realty Development Clam Bayou - Dinken Bayou, Old Blind Pass, Development and Boat Basins	1975 Proposed
24.	Caba-Ybel Yacht Basin now Tarpon Bay Marina	Pre 1960

Table 2 - Partial chronology of human developments affecting water quality and marine life in the shallow water ecosystems of Sanibel Island.

nutrient, and biotic transport, and allowed for the full development of several ecologically distinct marine environments. However, a number of natural and man-made features appear to be affecting the S.I.M.E.

Prior to 1961, San Carlos Bay was approximately 11,400 feet wide on a line from Punta Rassa to Point Ybel. The volume of tidal water passing this line probably circulates the S.I.M.E. from Point Ybel to the West Power Lines in Pine Island Sound. The S.I.M.E. west of the lines is probably circulated by tidal flow from Blind Pass, Redfish Pass and Upper Pine Island Sound. Construction of the Causeway islands and accesses have narrowed the effective width of the inlet from 11,400 feet (not counting the bridge supports) to 7,200 feet. Today the same quantity of water is "jetted" through a little over half the original inlet's width. We find catch evidence that the increased tidal velocities eliminated the only low intensity access the scallops had to the S.I.M.E., Pine Island Sound, Matlacha Pass and possibly Charlotte Harbor.

Physically, the increased tidal velocities through the South Channel have magnified the erosion of Sanibel's Dixie Beach. The numerous seawalls installed along the high tide line to abate the erosion have induced substrate scouring at the bases of permanent structures such as seawalls and stressed the adjacent marine grass beds. It is also clear that the old concrete jetties at the Lighthouse Point Condominiums, Point Ybel, are incompatible with the new Channel velocities. Here the strong ebb currents reflecting off the west jetty are eroding the shoreline. The jetties are also preventing natural shoreline processes from maintaining the beaches from Woodrings Point to Point Ybel, as is the Causeway bulkheaded approach ramp, the borrow pit just to the east of the ramp and the channel into Shell Harbor.

With respect to pollution problems, the currents through the

	Year(s)	Temperature °C	Salinity ‰	Turbidity	Dissolved Oxygen	B.O.D.	Total Bacteria	Coliform Bacteria	pH	Phosphates	Nitrates	Ammonia	Total N	Chlorophyll A	Organic Carbon	Primary Productivity	Bioorganisms	Plankton	Gulf	Pine Island Sound	Tarpon Bay	Sanibel River	Refuge	No. of Stations
Fincune and Dragovich (59)	54-57	X	X																X	X				7
Dragovich and Fincune (61)	57-59	X	X																X	X				3
Gunter and Hall (1965)	53	X	X																					2
Redtide Study	63-66	X	X					X									X	X	X					1
Odum et al.	52,55									X									X					2
Alberto et al. (1970)	68									X									X					2
Wang & Raney (1971)	68-69	X	X																X					3
Hour Glass Cruises	65-67	X																X	X					1
Good Charles & Jaap (73)	71	X	X	X														X						1
G. Hall & Associates (74)	73-74	X	X		X	X		X	X	X	X	X								X				3
D.P.C. (75)	73	X	X		X			X	X	X	X	X				X				X				1
Lee Co. Env. Poll. Ag. (75)	75			X					X	X			X			X				X				4
Woodburn (59)	59	X	X																		X			1
Phillips and Springer (60)	59	X	X	X																	X			2
Hancock (69)	69	X	X		X																	X		13
Provost (71)	71			X																		X		7
Fla. DPCSWR (75)	74	X	X	X	X																X			10
"Ding" Darling Refuge	66-75	X																				X		5

Table 3 - Summary of water quality studies containing data relevant to the inshore waters of Sanibel Island.

South Channel can transport pollutants to the Dixie Beach and Point Ybel beaches. Pollutants of concern encompass discharges from ditches, canals, yards, eroding shorelines, marinas and drainfield seepages released into estuarine areas. Further, these same tidal current patterns (with and without wind assistance) are such that an oil spill almost anywhere in the Intracoastal Waterway paralleling Sanibel would almost certainly be carried rapidly into Sanibel's delicate estuarine system or channeled onto the Dixie Beach shoreline. (Note: At least one barge load of oil per day passes from Boca Grande to the Florida Power Light tanks east of Ft. Myers via the Intracoastal Waterway channel.

Lack of circulation creates problems, too. Many examples of poorly designed and constructed tidal ditches, canals, marinas and lagoons can be found in the S.I.M.E. The effects of poor tidal circulation are notable in the following systems which can be considered in three groups according to similar characteristics.

The first group are internal excavated canals and lagoons, including the Lighthouse Point Condominium lagoon, the Shell Harbor canals,

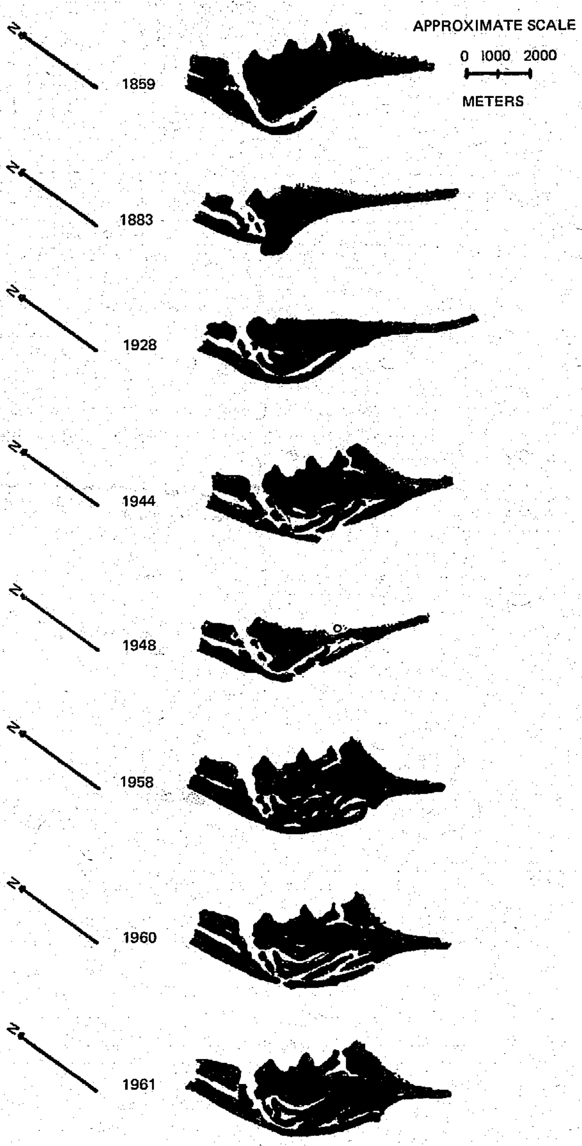


Fig. 3 - History of Blind Pass, Sanibel-Captiva Islands, 1859-1961 (After Duane Hall and Assocs., 1975)

extremities of the Sanibel Estates canal system, the Sanibel Harbor canal, the Sanibel Isles canals, the north and south ends of the Dixie Beach Boulevard canal, the Tarpon Bay mosquito control canal, the Pool, the Caloosa Shores lagoon, the Dinken Bayou canal, the Del Sega canals and especially the Castaways canal off Mud Pond.

The second group are tidally deprived areas due to artifical impoundment and are reviewed as follows:

The "Dunes Preserve" is a 70-acre tract of tidal mangroves that have been isolated by the construction of Dixie Beach Blvd., an act which stressed the system and set the stage for a recent kill caused by the Dunes Development dewatering program -- water was pumped from excavations into the tract and caused a nearly complete kill of the mangrove. Although a large culvert was installed early in 1974 and forty acres were seeded (22,000 seeds in July 1974), most of the tract is still effectively deprived of adequate tidal circulation. This situation will most likely inhibit successful recovery of the area and severely limit its biological productivity potential with a substantial loss to the Ladyfinger Lake and Tarpon Bay subsystems. Additional large culverts, strategically located under Dixie Beach Boulevard would do much toward restoring the historic tidal regime and biological role of the preserve.

The "Ding Darling Refuge Impoundment" is a similar situation on a larger scale. Here, the sand-shell dike/road prevents tidal penetration from reaching what appears to have been a productive marine nursery habitat of mangroves and shallow bayous. Seasonal rains appear to be insufficient for maintaining a balanced aquatic habitat. The area appears as a highly unstable, artificial brackish habitat effectively isolated from the adjacent estuary. It seems that corrective measures taken soon could restore the area.

The third example of tidally depressed areas are tidal mosquito control ditches. The two sets of ditches observed (those entering Tarpon Bay west of Gumbo Limbo development and those entering the canoe trail to Mullet Lake) were relatively deep (5-6 feet below MLW) compared to the lands they drain (from MSL to +2 feet). Excavated material was piled along each side of the ditches and some ditches are cut well into the uplands. They are poorly flushed by tides most of the year, during which time they act as sediment traps for materials that enter them via leaf fall, runoff, erosion and tides, thus decreasing the quantity of sediment and nutrients reaching estuarine areas. When these ditches are flushed, during storm runoff periods, the channelized runoff may stress the sensitive estuary system by injecting large quantities of sediment and nutrients in a sudden manner. In some cases the ditch spoil may be impeding tidal sheet flow among the transected mangroves. Corrective action includes cutting the ditches off from the estuary and filling them in.

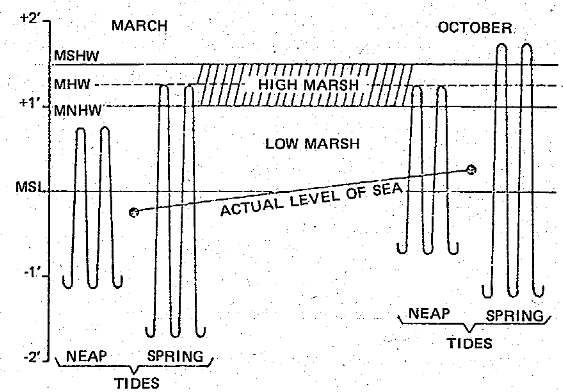


Fig. 4 - Diagram illustrating how, in Florida, the same tide intervals can flood the high marsh or mangrove swamp continuously at one time of the year and not at all at another. MSHW, mean spring high water; MHW, mean high water; MNHW, mean neap high water; MSL, mean sea level. (After Provost, 1974)

Wind Factors: Daily and seasonal winds play an important role in all aspects of the S.I.M.E. (See pIIA-12, Summary of E. Gulf of Mexico, 1973). The importance of wind to the estuarine biota is critical since shallow estuaries are often poorly circulated by tidal mechanisms alone. Wind is often responsible for moving water to and from the inlets and dispersing nutrients and plankton. The stronger, northerly, winter winds annually generate wave patterns that can (and do) create steep-sloped, high energy beaches along the Gulf beaches, and simultaneously create shoals while eroding the north-facing red mangrove shorelines along the Sound. Sustained northerly winds can hold the Sound in a low tide phase for several days at a time, sporadically exposing the shallow's marine biota to freezing air temperatures and other stresses (See Storey and Gudger, 1936, for Mortality of Fishes Due to Cold at Sanibel Island, Fla., 1886-1936; and Storey, 1937).

Conversely, the prevailing southerly winds of summer are comparitively gentle (except accompanying thunderstorms) and create low profile, low energy beaches on the Gulf. These winds also promote more deposition than erosion along the bay side. Occasionally more enduring southerly winds will compound tidal intensities and durations. These prolonged high tides may seasonally flood the more "upland" mangroves and add their litter to the detrital food base of the estuaries.

Two recommendations logically come from such considerations:

(1) Access channels should not be permitted which cut across the shoals protecting the mangrove shoreline from wave generated erosion.

(2) High rise construction should be discouraged along the bay side where it could deflect winds which would normally circulate the adjacent estuarine waters, i.e., the west end of Sanibel near the bayous and along Wulfert Bay.

WATER QUALITY AND SEDIMENTS

Historically, the water quality of the shallow water marine ecosystems of Sanibel Island exhibited seasonal and annual fluctuations under the interplay of waters from the Gulf of Mexico; Pine Island Sound; Matlacha Pass; the Caloosahatchee River; and the upland surface runoff, ground water seepage and mangrove bayous components of the Sanibel-Captiva Island system. The quality of the Island's marine waters has been affected (if not locally stressed) by a variety of human developments since the flood control dams on the Caloosahatchee River and the diversion of the Sanibel River from its historical exit on the Gulf side to Dixie Beach via the Sanibel Estates shallow canal system in the early 1940's. With the exception of septic tank development along the Sanibel River and mosquito ditches, the effects of various developmental activities on water quality are not easy to assess (Table 2).

At the present time, the marine waters adjacent to Sanibel are classified by the State as Class II waters

Station	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
5	34.0	25.9	28.9	22.8	29.9	30.6	29.2	31.3	32.3	31.5	32.8	33.6
4	32.3	27.2	31.6	25.7	30.8	33.3	31.9	32.4	32.8	31.5	35.1	32.3
3	34.9	30.7	33.1	33.8	34.3	34.0	32.4	34.4	34.2	32.1	36.4	36.2
2	31.2	25.8	28.8	30.4	34.8	33.3	31.9	33.1	33.6	32.1	34.2	35.3
1	29.5	23.0	29.7	28.2	32.9	33.3	31.9	33.0	33.4	32.1	34.2	35.3
6	36.6	26.1	30.9	30.6	34.1	32.7	31.0	32.6	33.7	29.5	35.5	34.9
7	37.9	22.6	24.0	33.1	34.8	35.5	30.5	32.6	33.6	31.5	35.5	38.9
8	33.3	17.4	23.3	31.2	34.8	28.8	30.2	32.6	33.5	30.4	35.5	34.9
9	32.9	12.0	22.4	24.3	28.9	28.8	26.0	30.3	34.2	27.6	35.1	37.2
16	27.3	22.0	28.0	27.7	29.3	29.9	30.5	33.3	32.7	25.4	33.8	32.3
17	31.2	25.8	29.3	29.0	30.1	31.2	31.8	33.2	33.4	26.7	34.2	34.9
18	34.0	29.0	30.9	33.2	31.8	31.1	30.5	34.6	33.3	33.2	35.1	36.2
19	34.0	21.5	26.9	30.8	29.9	29.9	29.8	30.7	32.8	29.3	33.8	34.9
20	29.9	21.7	29.4	35.1	33.6	30.7	31.3	33.0	33.6	33.2	32.8	34.9
21	22.2	16.3	22.1	25.6	30.3	28.8	31.1	32.9	32.3	28.0	27.5	32.7
22	22.2	16.9	22.1	26.9	29.7	29.3	30.0	31.6	32.0	25.6	28.9	32.7
23	16.9	11.5	21.5	28.1	27.6	24.8	28.0	30.0	31.0	17.4	30.2	32.7

Table 4 - Monthly surface salinities (0/00) at stations 21, 22, and 23 in Pine Island Sound and San Carlos Bay. (After Wang and Raney, 1971). See Fig. 2 for location of sampling stations.

that are to be maintained as suitable for shellfish harvesting, recreation and management of fish and wildlife. The waters in the bayous in the vicinity of Blind Pass (now Class III waters) are characterized by the poor circulation and septic tank seepage (which was observed in June 1975) in the Castaway Estates dead end canal off Dinken Bayou.

Marine water quality data for the Sanibel Island area are contained in periodic investigations of fish and shellfish populations and red tides. Water quality sampling stations have been primarily in the deeper, open waters. Table 3 summarizes the water quality parameters reported in eighteen investigations between 1954 and 1975. Prior to 1954 the only water quality records for the Island are those associated with water temperatures during winter freezes (Storey and Gudger, 1936; Storey, 1937). Thus, in the section that follows on individual water quality parameters, we can provide only a general picture.

(1) Salinity - Temperature - pH

The salinity of the inshore waters on the Pine Island side of Sanibel Island ranges from 11.5 to 39.0°/00 with a mean of 24.9°/00 (Table 4, Figure 6). The variation in salinity is due to seasonal variation in rainfall (Table 1 and Figure 1), discharges from the Caloosahatchee River where salinities at the River's mouth range from 4.1-35.2°/00 (McNulty *et al.*, 1972; Gunter and Hall, 1965) and shoreward indrafts of the high salinity Florida West Coast cyclonic eddy of the Gulf of Mexico. Reports by Woodburn (1959), Phillips and Springer (1960) and Hancock (1969) indicate that the salinity and temperature in Tarpon Bay is similar to that in the adjacent Pine Island Sound. The surface water temperatures in the area are climatically influenced (Table 1) ranging from 35°C in summer to 10°C on occasions in December to February.

Salinities and temperature in the shallow waters of the mangrove bayous and the "Ding" Darling Wildlife impoundment area are subject to greater fluctuations than the waters around the island. Indeed, the monthly salinity records (Table 5) from five stations (Figure 8) for 1971 show that the salinity in the perimeter canal in the impounded area (Stations 1, 3, 4 and 5) varies spatially and seasonally as compared to that in East Sanibel Bayou (Station 2). In this respect the impoundment canal and flats form a miniature tidal estuary with characteristics of a hypersaline lagoon ecosystem.

Recorded values for pH in the Pine Island Sound area range from 7.8 to 8.2 (Figure 9), which is normal for inshore waters along this coast.

(2) Water Clarity (Turbidity)

From a human viewpoint, marine waters of high clarity and low turbidity are desired for swimming, fishing and boating. However, in the waters around the barrier islands of southwest Florida, one can rarely see the bottom in water greater than six feet except in the vicinity of tidal passes. In the waters around Sanibel Island Secchi disk readings at Stations 1 to 4 miles offshore in the Gulf may only be 4.5 to 7.5 feet (Goodcharles and Jaap, 1973). Turbidity values in Pine Island Sound over a twelve month period (1973-74) varied from highs in July, February and March to lows in October and November (Table 6). Field observations June 1975 on the north side of Sanibel indicate that the waters of the mangrove bayous, Ladyfinger Lake, and Tarpon Bay are moderately turbid. On the grass flats bordering San Carlos Pass-Pine Island Sound, the waters are less turbid and marine grasses may grow at depths of three to four feet MLW.

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1	22.5	38.1	52.6	43.7	41.1	31.1	9.2	7.8	7.8	10.9	20.9	23.3
2	31.4	34.1	38.9	40.7	41.5	32.2	22.6	18.9	21.6	26.4	32.8	34.3
3	18.7	24.3	32.9	36.8	38.9	29.6	10.7	5.3	6.3	7.2	10.3	11.6
4	18.1	24.2	33.5	44.9	45.3	31.3	10.2	4.4	5.9	6.4	8.1	10.1
5	8.8	12.4	18.1	25.2	25.4	15.8	1.7	1.4	2.2	2.0	3.0	5.4
Rainfall (Inches)	0.00	0.69	0.00	0.05	2.84	15.21	8.40	4.35	7.26	0.13	1.52	0.65

Notes: 1) Salinities taken on the 1st and 15th each month.

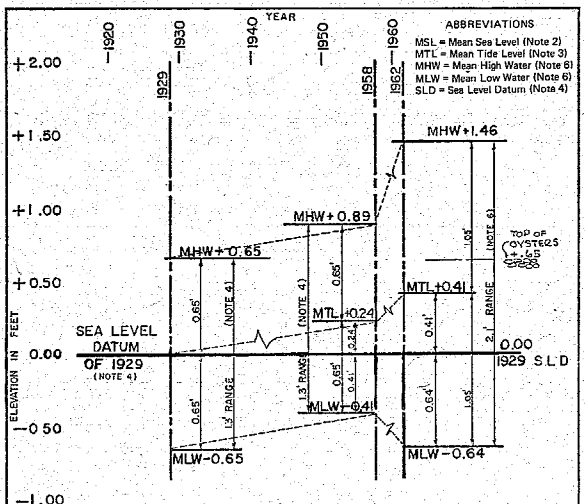
2) Complete monthly salinity data for all stations for 1971, 1972, 1973, 1974, 1975. Scattered data back to 1966. Available at the Refugee Headquarters.

3) Rainfall data from two main rain gauges (Refuge station and Refuge headquarters) for 1971, 1972, 1973, 1974, 1975.

4) Station 2 outside of impoundment area on East Sanibel Bayou side of dike.

Table 5 - Average monthly salinities ppt (%) at five stations in the impounded area of the J.N. "Ding" Darling Wildlife Refuge, Sanibel Island during 1971. (See Fig. 10 for location of stations.)

However, there are three exceptions to this general pattern of turbidity. One is the grass flat area off Coral Creek where marine grasses were clearly visible in six feet of water. The usual clarity of the water in this area may be due in part to its being the tidal node area between San Carlos Pass and Blind Pass. The second area is Wulfert Bay between Wulfert Point and Wulfert Keys. Here Secchi disk readings of 16 inches were recorded. Because of the fine sediments, the water was so turbid that the turtle grass growing in 28 inches of water was barely visible. But in an adjoining backwater area between Runyon Key and Wulfert Point the Secchi disk was not visible deeper than six inches. In this area and in lower reaches of Dinken Bayou the sediments consist of fine, marly muds and sugar sand one to two feet deep. However, in the adjoining tidal channel near the marina at Wulfert a Secchi disk reading of four feet was obtained.



1. This chart is based on data furnished by the U.S. Coast Guard and Geodetic Survey, and on "Shore and Sea Boundaries" by Shalowitz (published by U.S. C. & G. S.)
2. Local MSL should not be confused with sea level datum of 1929 as listed under item 4 since it is an adjusted datum based on sea level observations at selected locations.
3. M.T.L. is the plane midway between M.H.W. and M.L.W.
4. Official designation of the existing bench mark network at 0.00 elevation is "Sea Level Datum of 1929."
5. Available data indicates that the sea level (represented above by change in M.T.L.) has risen about 0.4 ft. in this area between 1929 and 1962, averaging about 0.012 ft. (0.15 in.) per year.
6. Prior to 1962 U.S.C. & G.S. computed tidal range as a "mixed tide," averaging all highs for M.H.W. and all lows for M.L.W. U.S.C. & G.S. now classifies this Gulf Coast tidal area as dominantly diurnal, and computes M.H.W. from only higher-highs and M.L.W. from lower-lows.

Fig. 5 - Tide levels at Sarasota Bay, 1929-1962. (After Smalley, Wellford and Nalven - Consulting Engineers, Sarasota, Florida, 1967)

From our ten-day field survey the turbidity of waters around Sanibel may be ranked as follows from worst to best: Dinken Bayou> Clam Bayou area> Wulfert Bay> Tarpon Bay> Ladyfinger Lake and Sanibel Bayou areas> Gulf Beach> Pine Island Sound grass flats> grass flats off Coral Creek Inlet. In each area the degree of turbidity results from a different combination of composition of suspended materials (plankton, fine detritus, inorganic silts and clays); bottom types; and wind, wave and tidal current generated turbulence. At the present time water clarity around Sanibel is due primarily to natural factors or to man's activities in other parts of the Pine Island Sound system.

(3) Sediments

The physical character of superficial bottom sediments in the waters around Sanibel Island not only affect water clarity patterns but also are partial determinants of the diversity of benthic marine plant and animal communities. Although no detailed studies of sediments in the S.I.M.E. have been completed, several reports that touch on this subject merit review.

Sediments in the Gulf around Sanibel consist of two zones of quartz sand similar to sediments currently carried by local streams and derived from coastal sands (Figure 10). Directly south and northwest of Sanibel the quartz-shell sand zones provide habitat for the important Sanibel pink shrimp fishing grounds. The Pine Island Sound sediments have a size distribution similar to various coastal lagoons along the extreme southwest Florida coast (Scholl, 1963).

In a recent study on the depositional history of Sanibel Island, Missimer (1973) discusses the physical character of the submerged beach ridges of the Island's oldest beach set Number 1 (Figure 11). This beach ridge set encompasses the shallow water bayou-mangrove ecosystem along the north side of the island from Tarpon Bay to Blind Pass. In this area the bottoms are covered by lagoonal muds containing varying amounts of detritus, quartz sand and decaying plant matter. The large low energy tidal flats in the Refuge Impoundment area contain mixtures of silts, clays and plant material averaging one foot thick over the underlying sands.

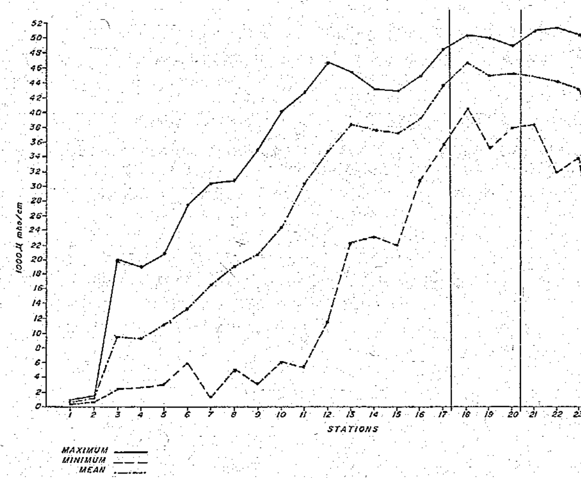


Fig. 6 - Specific conductance and salinities at water quality stations 18, 19 and 20, Pine Island Sound - San Carlos Pass, 1973-1974. (After D. Hall and Associates, 1974) See Fig. 7 for station locations.

In a study on the ecology of Sanibel mollusks, Haas (1940) briefly described several habitats as follows: On the San Carlos Pass side of the island at depths below five feet the bottom contains fine shell fragments. The grass flats along the Pass and Pine Island Sound are sandy with a surface layer of fine silt and organic matter (easily disturbed by prop wash and waves). The intertidal shoals consist of firm sand. The Tarpon Bay grass flat areas grade from firm sand to sandy mud to soft, silty sand from the channel toward Prawn Key. South of the channel the shore is bounded by an intertidal, firm sand shoal.

Historically, as recently as 1940, the innermost reaches of Clam Bayou and Old Blind Pass had a white sandy bottom (Haas, 1940). Today this area, as well as Mud Pond, is characterized by soft 12 to 18-inch deep lagoonal muds. The bottom of the lower reaches of Dinken Bayou and the area south of Albright and Runyon Keys consist of a unique soft, white-grey-marly sand mud up to two feet deep overlying firm sand.

Another unusual sedimentary area is the "rocks" about 1.5 miles west of Rabbit Road where there is an outcropping of coquina limestone (or "mussel bracchia") just off the beach which is periodically exposed and covered by sand. Haas (1940) suggested that this would be a favorable area to study the origin of such limestones. The rock is relatively soft and fragmented by storm waves. Our field observations showed that the rock consists of sets of thin layers of rock with crevices. Locally, it is a prime surf fishing area. Geologically, it may have played and may continue to play a key role in the littoral drift erosion and accretion processes that have shaped the Gulf side of the Island.

A third unusual sedimentary area is the fluid sandy shoal off of Point Ybel. Here the quartz-shell sand is constantly moving under the force of tidal currents. This was the one inshore subtidal area where we observed populations of the sand dollar, <u>Mellita quinquiperforata</u>.

A fourth unusual sedimentary area is composed of material accumulating in man-made canals and deep tidal ditches along Dixie Beach Blvd. and the dike of the Refuge Impoundment. In these areas, organic-rich, fluid sediments are accumulating annually. In the canals along the Refuge dike these sediments are two feet thick. In the various development canal systems these sediments are one to two feet thick. It has been well documented in recent literature on canal systems that these sediments support a few species of benthic organisms and lower water quality.

(4) <u>Dissolved Oxygen and B.O.D.</u>

These two parameters are of major importance in judging water quality, but data for the Sanibel Island marine waters are sparse and limited primarily to surface water sampling stations along the Intracoastal Waterway (Fla. Dept. Pollution Control, Oct.- Nov. 1973, San Carlos Bridge; D. Hall & Associates, 1974. Maximum D.O. values of 8.0 and minimal values of 5.0 at three stations off Sanibel over a 12 month period (Figure 12) indicate that water quality in this region of the Sound and San Carlos Bay is good.

This is reflected in the five-day B.O.D. values from two of these stations (Figure 13).

One may conclude that the waters entering the Sanibel enclosed water "areas" (bays, creeks, etc.) on flood tides are of high quality. However, the waters leaving them may well be of lower quality due to degradation processes in the inshore waters and man-made dead end canal systems. Studies on the east end of Sanibel River by the Florida Dept. of Pollution Control (1974), the west end of the Sanibel River by a Windham College study team (1975) and the

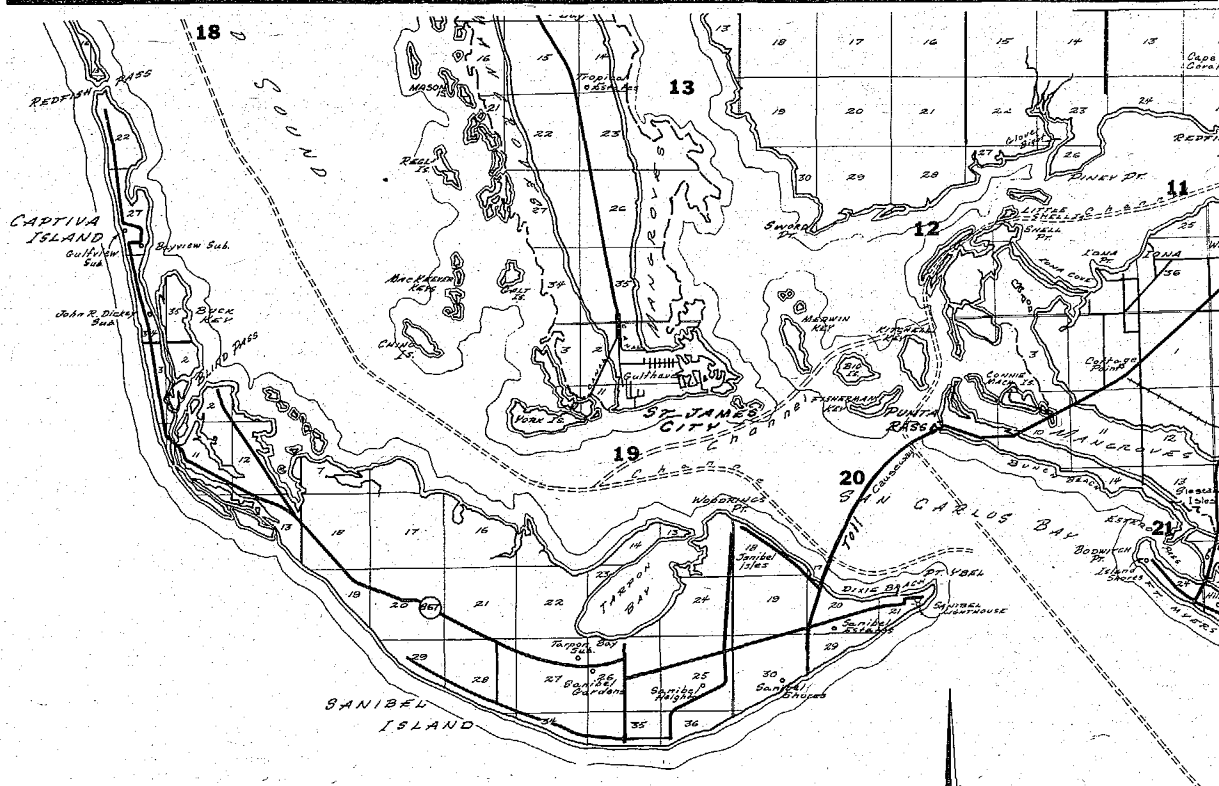


Fig. 7 - Water quality sampling stations, Jan. 1973 - Nov. 1974. (After Duane Hall and Assocs. 1974)

mosquito control canal in Tarpon Bay by Hancock (1969) indicate that water of low quality is entering Tarpon Bay and possibly the Shell Harbor Canal system from the upland Sanibel River drainage basin.

Given the current emphasis on dissolved oxygen values in waters around human developments as compared to "natural" conditions by regulatory agencies, an extensive water quality monitoring program is required for the disturbed and natural portions of the Sanibel Island inshore and estuarine waters to establish a baseline. Such a program should include 24 to 36 hour sampling regimes at close intervals (at least once/month) on appropriate ebb-flood tides sequences and under a variety of weather conditions (i.e., following heavy rains).

(5) Nutrient and Nutrient Supply

The well-being of natural systems on and around Sanibel Island is in part dependent on the marine plants (mangroves, grasses, macro-algae and phytoplankton) which, in turn, are nourished by dissolved inorganic minerals and bioorganic substances (i.e., vitamins, amino acids, carbohydrates). Nutrients for marine plants around Sanibel are derived from the Gulf waters, the mainland rivers, the runoff from Sanibel Island, the metabolism and decomposition of marine plants and other marine life, and the release of nutrients from marine sediments in and around the Island. At the present time our knowledge of the nutrient budget in the various segments of the Sanibel ecosystem is fragmentary. Until recently the thrust of nutrient studies in the Sanibel marine waters was directed toward understanding the casual mechanisms of "red tide;" now such studies focus on compounds of nitrogen and phosphorus because of their general role in plant growth and eutrophication.

In December 1953, H.T. Odum recorded total phosphate values of 0.025 and 0.032 ppm at Sanibel Island and 0.073 ppm on the Caloosahatchee River at the Ft. Myers pier. At the time the Sanibel values were below the mean total phosphate of 0.044 ppm for estuaries outside the phosphate district of central-west Florida (Odum, 1953). More recently Alberts et al (1970) recorded similar total phosphate concentrations in the surface waters of Pine Island Sound (Figure 14). In their 12-month study (1973-74) D. Hall and Associates (1974) recorded monthly variations in total and ortho phosphate at their China Island Station 18 near Sanibel (Figure 15, Table 7). Total phosphate concentrations ranged from 0.02 mg/l in February to 1.69

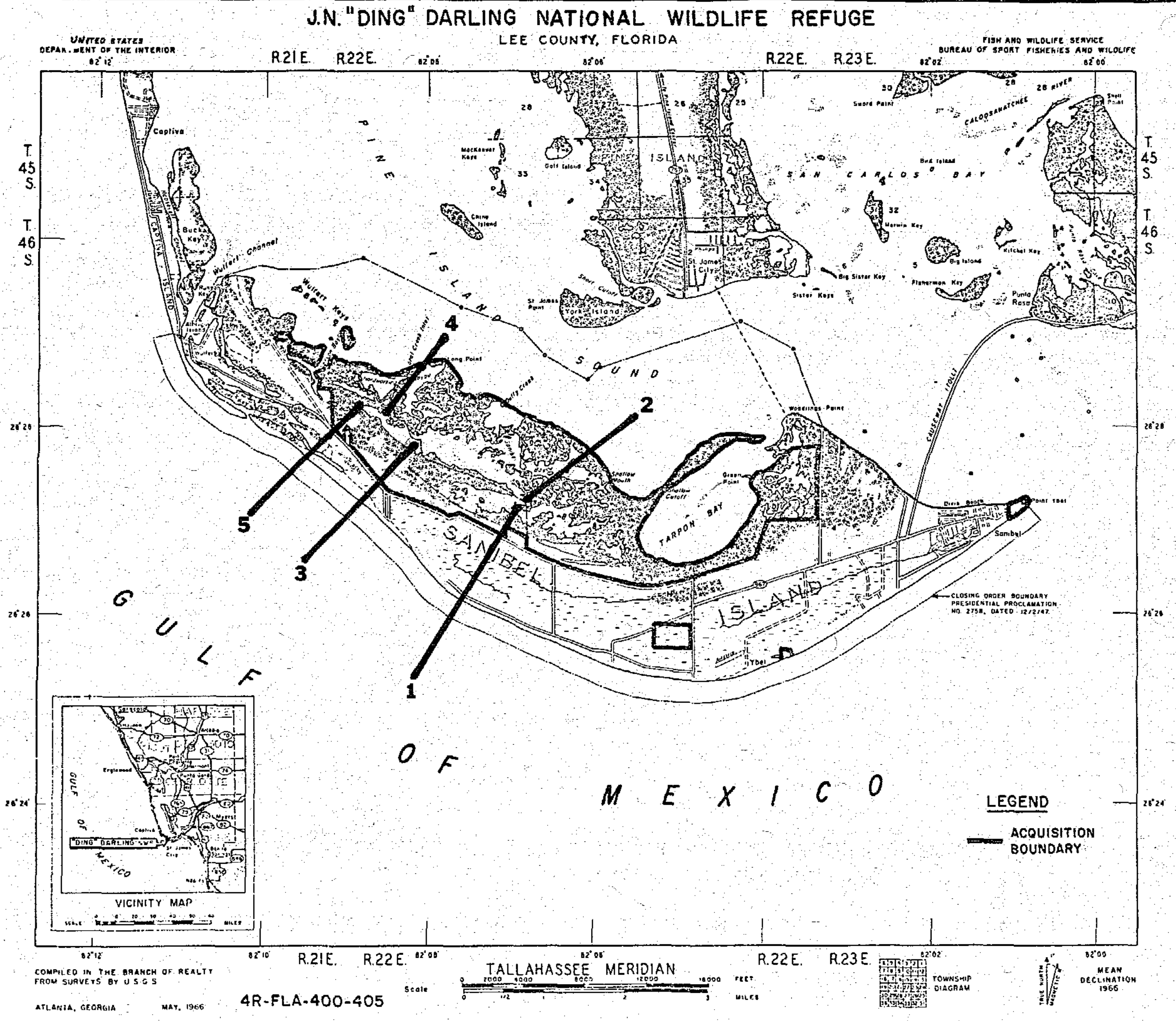


Fig. 8 - Location of salinity stations in canal along impoundment road-dike of J.N. "Ding" Darling Natural Wildlife Refuge.

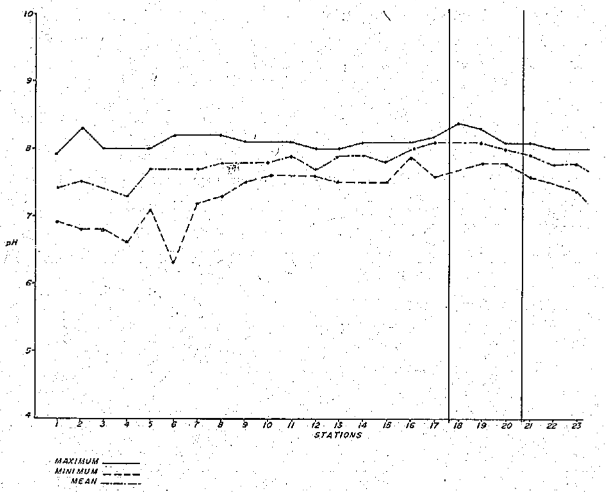


Fig. 9 - Monthly pH values for stations I8, I9, 20 (1973-74) Pine Island Sound - San Carlos Pass. (After D. Hall and Assocs., 1974.) See Fig. 7 for station locations.

mg/l in August. The complexity of interpreting the causes of monthly variations in concentrations of total phosphate is seen by comparing Figure 15 for total phosphate with Figure 16 for nitrogen, Figure 1 for rainfall and Table 6 for turbidity.

In this same study concentrations of nitrate, ammonia and total nitrogen exhibited monthly variations (Figure 16). It appears from this figure that nitrate presently is sufficiently low in Pine Island Sound to limit the excessive growth of marine algae and phytoplankton around Sanibel.

It is unfortunate that the available studies do not tell us whether Sanibel is significantly fouling its inshore estuarine waters. Clearly septic tank leaching field seepage along the developed shores and canals and along the Sanibel River slough system and mosquito ditches enters the upper reaches of the marine system thereby enriching these waters. But it is difficult to assess the relative contribution of nutrients from upland sources compared to nutrient release from organic sediments in upland canals and mosquito ditches and to bird feces of the large waterfowl populations of Sanibel.

Biological-Ecological Considerations

MARINE RESOURCES

Shelling, fishing and birding rank high among the amenities that attract visitors and residents to Sanibel Island. However, today the islanders agree that shelling and fishing are not like in the "good old days" before the Causeway. Tourists, too, express disappointment in the monotony of the kinds of shells along Sanibel's Gulf shores and in the apparent small catches of sport fishes. Since impressions are often based on colored memories and hearsay, we introduce this section with brief comments on selected marine resources.

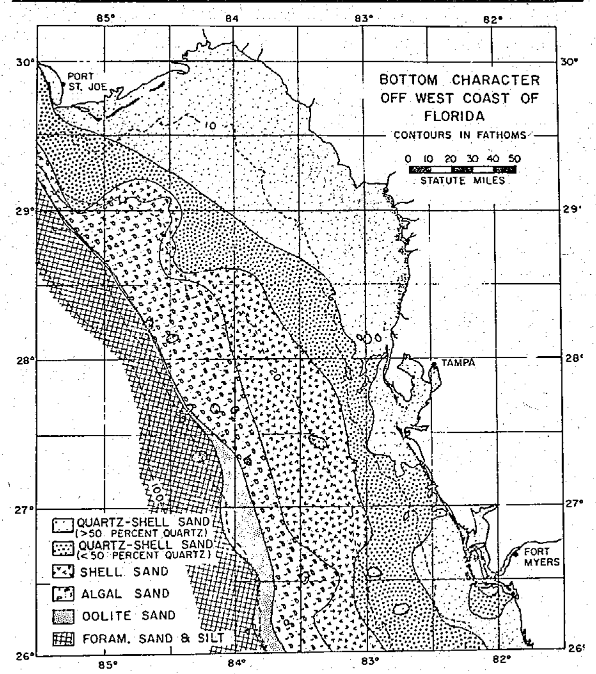


Fig. 10 - Sediment distribution on West Florida Shelf. (From Rezak and Edwards, 1972)

[Fig. 11 - (Appears as Fig. 6 in Hydrology Appendix)]

(1) <u>Shells</u>

The romance of shelling has made Sanibel famous. It has lured thousands of people to this island over the years and with good reason. According to Perry and Schwengel (1955): "The abundance and variety of the marine molluscan fauna of the Sanibel-Captiva region is unexcelled by any other in America, and by few areas of like extent elsewhere." This is due to the mosaic nature of the bottom environments inshore, offshore and in the estuarine areas of Sanibel; current patterns; slight modifications of salinity; and geographic location where ranges of southern and northern species overlap.

The number of species of mollusks living in the Sanibel area is truly impressive although the actual number reported in the literature varies (Perry; Haas, 1940). The variety of species in four major classes of mollusks is as follows: Amphineura - 3 species; Gastropoda (snails) - 198 to 250 species; Scaphopoda - 7 species; Pelecypoda (bivalves) - 120 to 152 species. In spite of this variety the beginning shell collector is likely to find no more than 24 kinds of living or dead mollusks. In this study on the ecology of mollusks of Sanibel, Haas (1940) pointed out that the "vast mortuary" of shells on the beaches was 99.9 percent mussel shells with shells of snails making up the other 0.1 percent. Of the other bivalves on the beaches most were ark and pen shells which normally live in the firm sand bottoms offshore in vast numbers. One may appreciate the dimensions of these populations by the numbers of pen shells that accumulate on the beaches after storms (the best time for shelling). In one instance at the northwest corner of the island a festoon of dead pen shells 12 to 15 feet wide and 7 inches deep was estimated to have one million shells (Haas, 1940).

In a four day census of the Gulf beaches of Sanibel in March 1976, penshells were the most conspicuous. Other

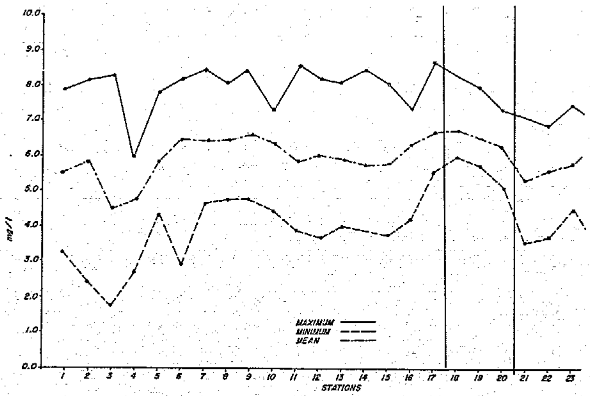


Fig. 12 - Dissolved oxygen, Intracoastal Waterway, 1973-1974. (Note stations 18, 19, 20.) (After Duane Hall and Assocs., 1974) See Fig. 7 for station locations.

common bivalves included dead and live calico scallops, cockles (6 species), ponderous ark, cat's paw, broad-ribbed cardita, chione (2 species), Venus (2 species), surf clams, Dosinca, and coquinas. Some 20 species of bivalves were common while only three species of snails were common.

(2) Fishes

Over 70 species of marine fish have been reported to inhabit coastal waters off Sanibel (Tables 8 and 9). Most are shallow water species whose habitats and food preferences are as varied as the habitats from which they are usually caught. As part of the Pine Island system, they are irreplaceable fish breeding and nursery grounds. The estuarine waters of Sanibel are frequented by sports and commercially important species. This complex ecosystem is important as a fishery resource not only for man, but also for waterfowl. Such extraordinary species as the bottle nose dolphin and the manatee also depend on the system.

At the present time the only commercial fishing activities around the island are permit-regulated gill netting in the bayous of the Refuge, bait fish otter trawling around the Prawn Key grass flats and a bait shrimp roller trawl operating in Tarpon Bay.

If in the future the estuarine fish resources around Pine Island suffer depletion from urbanization, the waters of Sanibel Island may experience more intensive commercial fishing activities. Such activities may compete with waterfowl and sport fisherman and conflict with the esthetics of the Island's residents living along the shore; accordingly, we recommend that some forethought be given to this potentially inflammable socio-economic problem.

(3) Avian Resources

Sanibel can claim one of the longest bird checklists in the State. It is significant that many of these species depend directly on the marine life of the surrounding waters. In fact, the diversity and sheer numbers of these birds reflect the abundance of the marine resources upon which they depend. Protecting the Island's bird populations necessarily involves identifying and protecting these resources; i.e., what and where they eat; where they roost; and where they nest.

From our field observations alone, we can safely say that literally all of Sanibel's surrounding waters and bay bottoms play a critical role in supporting the resident and transient marine bird life. Here we discuss only those locations that involve conflicting interests and someday may require special protection.

Most of the marine birds feed along the shorelines and/or in the shallow waters. In general, all of the beach, shoal and mangrove shorelines are select feeding grounds for herons, egrets and the many different shore birds. Further, several species (notably the Little Green Heron and the Osprey on the bay side and the terns, skimmers, etc. on the beaches) prefer to nest along the coastline. Accordingly, we recommend that all coastal shorelines not be disturbed or developed. Where these areas are not already preserved, purchase and/or strict regulation is needed. A comprehensive beach nesting program should be developed for the open sand nesting species, as well as sea turtles. Such a program might be aimed at developing nesting areas (behind dunes at Turner's Beach) and controlling public usage during the breeding and nesting seasons.

The main threat to avian feeding and nesting along the bay side are projects which create steep tidal slopes and remove the native vegetation; i.e., waterfront developments having door-to-shore yards with seawalls and usually a boat channel or basin. Our first recommendations would be to protect all remaining estuarine shorelines and their associated mangrove forest, however far they may extend inland, including possible strategic purchase through the State's environmentally endangered Land program. Specifically, the Ladyfinger Lake mangroves behind Woodrings Point and the mangrove forests at the west end of the R Refuge (Kesson Bayou), along Wulfert Point and as much of the west end bayou system as possible, including Runyon and Albright Keys should be protected

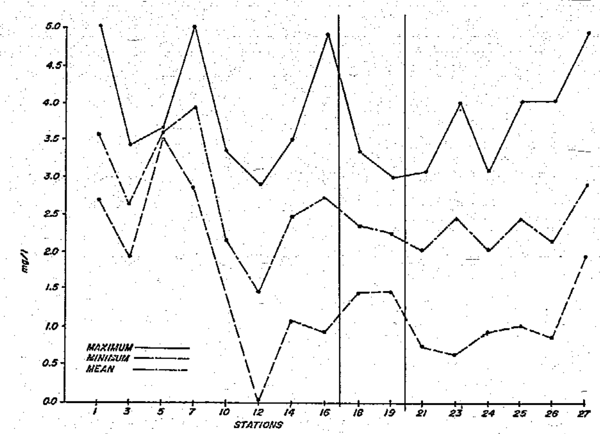


Fig. 13 - Five day B O D values for water quality stations 18 and 19. (After D. Hall and Assocs., 1974) See Fig. 7 for station locations.

The shallow waters behind the Sanibel Shoals and at the mouth of practically every bayou inlet are easily identified as major feeding grounds. Here large numbers of herons, egrets, spoonbills and shorebirds can be observed feeding during a low tide. (Many of these same areas have sufficient quantities of table foods (clams and pen shells) and live specimen shells in addition to the many small fish, shellfish and marine worms sought by the birds.) Once these resources are "discovered," over-zealous harvesting and collecting typically follows, seriously disrupting feeding schedules and devastating the delicate ecological balance of these areas.

A complete plan of protection is required. A possible approach is for the City to request the State Department of Natural Resources to declare the "Sanibel Shoals Feeding Grounds" as a bird sanctuary and allow no harvesting or shell collecting or power boating in the shallows (in waters less than three feet below Mean Low Water) the length of Sanibel.

		STATIONS											
		1	3	5	7	10	12	14	16	18	19	21	23
1973	JAN.	3	1.6	0.8	0.8	0.8	0.8	1.2	0.8	0.8	0.8	1.6	2.4
	MAR.	4	2.4	1.2	2	1.2	0.8	1.2	1.2	1.2	1.6	1.2	2
	APR.	—	—	—	—	—	2.4	4	3.6	2	2.4	2.4	3.2
	MAY	4.8	4	2.8	1.6	1.6	1.2	2	1.2	1.2	2	4	2
	JUN.	6	3.6	2.4	2.8	2.4	1.6	2	3.2	1.6	1.6	1.2	2
	JUL.	14.7	4	17.6	13.5	8.8	5.5	4	1.2	3.2	2.8	2.8	2
	AUG.	17.6	17.6	11.8	13.4	4	4	1.2	14.7	1.2	1.2	1.2	1.2
	OCT.	6	6	17.6	11.8	4	0	0	0	0	0	0	2
	NOV.	2	0	2.5	1	5	0	2.5	0	0	0	0	0
1974	FEB.	0.81	1.5	3.2	2.5	1.1	1.5	1.8	2.7	2.8	3.1	3.5	1.4
	MAR.	1.0	1.1	7.1	5.0	1.5	1.3	2.2	4.1	1.5	3.0	2.0	—

Table 6 - Monthly turbidity values at Intracoastal Waterway stations 18 - 19 (1973-1974). (After D. Hall & Assocs., 1974.) See Fig. 7 for stations.

Several major roosting areas and a few osprey nests were observed. These are within protected areas and do not appear to be under any present or future threat. However, they have been indicated on the major resource map.

ASSESSMENT OF ECOLOGICAL RELATIONSHIPS

The marine communities of Sanibel Island include those fish, plankton, macrobenthic algae, sea grasses, non-vegetated benthic areas, algae mats, mangroves, oyster bars and solid substrates such as The Rocks, pilings, seawalls and mangrove prop roots. All relate to human vested interests on the island and may be affected by human activities.

The occurrence of phytoplankton and their seasonal presence-abundance in the waters adjoining Sanibel are sketchily recorded in studies by Davis (1950), King (1950), and Williams and Ingle (1972). General seasonal distribution patterns of dinoflagellates and diatoms near Sanibel are presented in the 1963-66 Red Tide Symposium (F.B.C.M.L., 1967).

The outstanding effect of the plankton community on the island's human population involves periodic red tides that result in fish kills. The accumulation of dead fish along the island's shores during the following red tides and other environmental perturbations like winter freezes is an environmental nuisance with which the City and citizens should be prepared to cope. Historically, accumulations of fish were used as fertilizers; today, most barrier island communities treat such accumulations as garbage. We recommend the former as the more environmentally sound means of dealing with this nuisance.

The description and assessment of the inshore-estuarine, benthic communities at specific locations that follows are based on aerial photos and a ten-day field survey

		STATIONS											
		1	3	5	7	10	12	14	16	18	19	21	23
1973	JAN.	0.21	0.36	0.36	0.42	0.23	0.21	0.15	0.38	0.17	0.13	0.13	0.16
	MAR.	0.72	0.78	2.13	0.53	0.36	0.27	0.59	0.47	0.47	0.71	0.96	0.13
	APR.	—	—	—	—	—	0.07	0.10	0.10	0.08	0.08	0.08	0.04
	MAY	0.25	0.78	1.56	0.60	0.62	0.67	0.76	0.78	0.54	1.38	0.10	0.55
	JUN.	0.20	0.24	0.26	0.68	0.20	0.52	0.34	0.12	0.18	0.40	0.36	0.12
	JUL.	0.67	0.71	0.67	0.37	0.43	1.25	0.31	0.37	0.25	0.49	0.60	0.18
	AUG.	1.66	2.64	0.80	0.92	1.07	0.86	0.86	1.54	1.69	0.37	0.80	0.66
	OCT.	0.13	0.84	0.90	0.60	0.32	0.22	0.24	0.42	0.70	0.20	0.18	0.24
	NOV.	0.78	0.96	1.32	0.52	0.01	—	—	0.52	0.52	0.24	0.46	1.64
1974	FEB.	0.05	0.05	0.16	0.09	0.09	0.02	0.02	0.03	0.02	0.02	0.01	0.01
	MAR.	0.03	0.06	0.28	0.15	0.07	0.06	0.12	0.24	0.05	0.08	0.06	0.05

Table 7 - Monthly total phosphorous concentrations (mg/l) at Intracoastal Waterway stations, 1973-1974. (Note stations 18 and 19.) (After D. Hall and Assocs., 1974.) See Fig. 7 for station locations.

supported by various published (Haas, 1940) and unpublished reports (Florida State Dept. Nat. Res.).

POINT YBEL TO WOODRINGS POINT (BAY BEACH)

The shallow grass flat zone between Point Ybel and the Sanibel Causeway is narrow and subjected to strong tidal currents. The bottom is of shelly sand. This is the only area where we found the sea urchin, Lytechinus variegatus. In the intertidal sand zone patches of short blade Cuban shoal weed occur. In the slightly deeper zone are mixed patches of manatee grass, Cuban shoal weed and turtle grass. This zonation is interrupted by the Lighthouse Point Development seawalled canal, the entrance to Sanibel Estates marine canal system and the Causeway.

Between the Causeway and Woodrings Point, the intertidal sand beach zone is bordered by a narrow sandbar with patches of Cuban shoal weed. Stands of turtle grass predominate on a firm sand bottom in slightly deeper water.

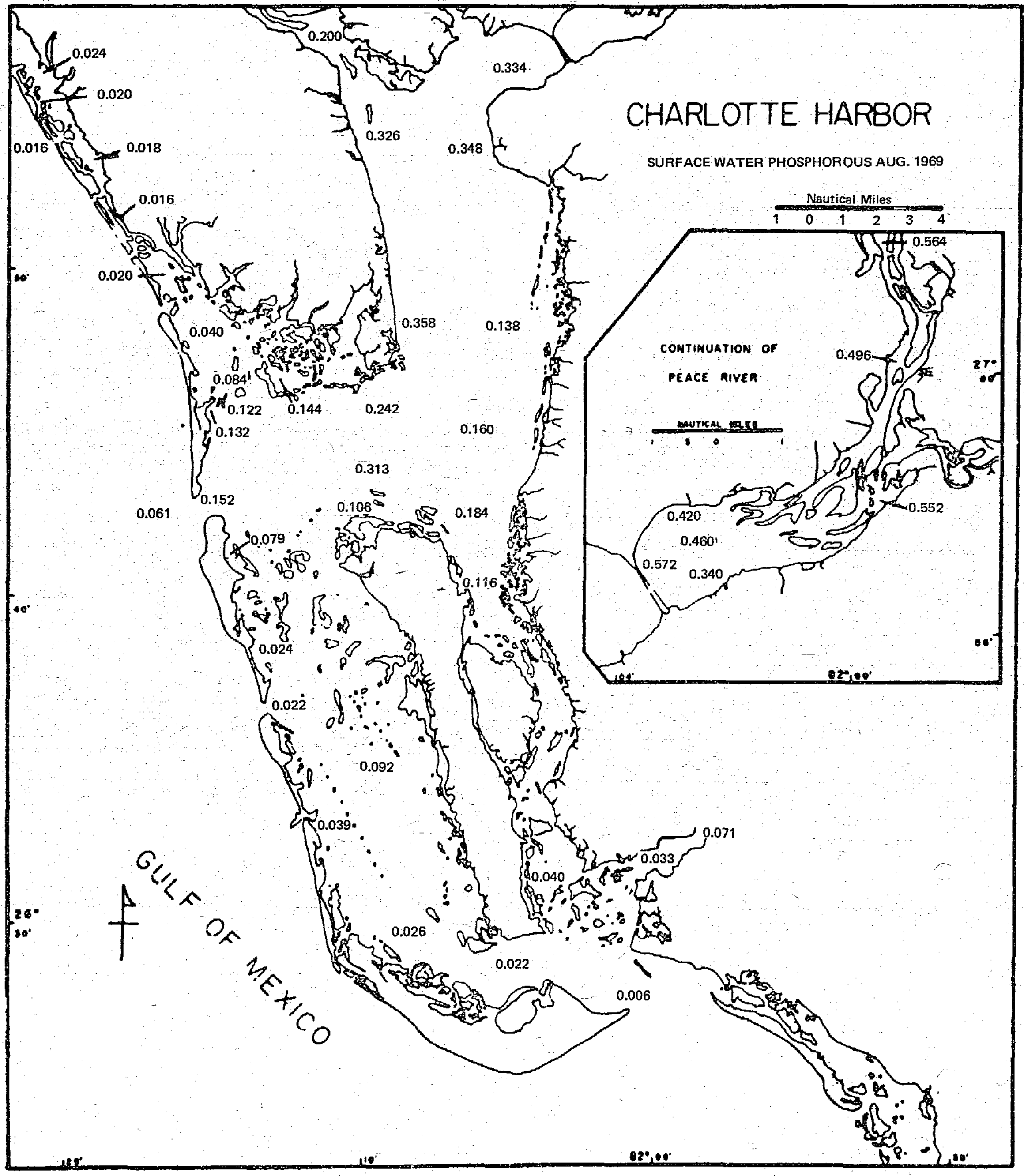


Fig. 14 - Surface water phosphorus (ppm), Aug. 1969 in Pine Island Sound, adjacent to Sanibel Island. (After Alberts et al., 1970)

The beach dynamics along this shore are such that seawalls even at the storm tide line and bulkheaded upland canal entrances promote the steepening and loss of beach and reduction in the narrow fringe of marine grasses along the channel. Piers, however, do not adversely affect the shoreline or the intertidal shoals.

TARPON BAY

Rounding Woodrings Point one enters Tarpon Bay with its natural meandering clay bottom channel five to ten feet deep. A series of long, narrow intertidal oyster bars parallel the upper reaches of the channel. North and south of the channel the bottoms shoal and are covered with a mixture of Cuban, turtle and manatee grass. Populations of hard shell clams, pen shells and sea squirts (Molgula occidentalis and Styela partita) reside in the grass beds in the central parts of the bay. On the south side of the bay between Green Point and the mosquito control canal, the shore is bordered by an intertidal sand bar. Cuban and turtle grass beds form dense meadows between the bar and the shore. Bayward of the bar the grasses are patchy but drifting red algae (i.e., Gracillaria sp.) are abundant. Although the grass beds do not extend beyond the four foot contour line, the red algae do. Thus, nearly the entire bottom of the bay is populated with macroflora and their associated fauna including juveniles of pink shrimp, tarpon, snook, sea trout, red fishes, snapper and a variety of micro and macro-epiphytic algae, protozoa and invertebrates.

The north side of Tarpon Bay lacks an intertidal sandbar. The bottoms along the protected shores are less densely vegetated and have soft silt sediments. Nevertheless, this region of the bay is highly productive as evidenced by the presence of hard shell clams, young shrimp, blue crabs and twenty species of fish collected in a preliminary survey of Woodburn (1959).

At the present time the only direct developmental intrusions upon the bay are a tidal canal discharging from the Palm Ridge Development, the Tarpon Bay Marina and the mosquito control canal. Intertidal oyster bars have developed at the entrance to the marina. Other oyster bars are developing near the mosquito ditch exits on the south side of the bay.

LADYFINGER LAKE SYSTEM

South of the entrance to Tarpon Bay one enters Ladyfinger Lake through a branching tidal channel between red mangrove islands. The scoured bottoms of the channel support an epibenthic community of algae and invertebrates characteristic of clear tidal creeks. Solitary and colonial tunicates, encrusting bryozoa, the handsome coral-like, orange and purple bryozoan (Schizoporella unicornis), market-size oysters, crabs, the purple soft coral (Leptogorgia), sponges, and attached macro algae which are a delight to free divers inhabit these channels. The benthos as well as the well-developed intertidal prop root communities bordering these channels make the channels one of the island's unique marine educational resources and also one of its most attractive fishing areas.

Ladyfinger Lake proper is of sufficient depth and clarity to be vegetated primarily by "healthy" stands and meadows of turtle grass. Macro-red algae tend to accumulate in depressions. At the west end of Ladyfinger Lake are a series of tidal lagoons in the mangrove forest. Here, stands of turtle grass and Cuban shoal weed yield to dense beds of green algae typical of South Florida mangrove lagoons where tidal circulation is sluggish. This region is navigable by power boat only at high water.

MULLET LAKE - MANGROVE LAKE SYSTEM

Immediately west of the mosquito control canal in Tarpon Bay is the entrance to a lovely tidal creek and the Canoe Trail of the Refuge. The prop roots and aerial roots of the red mangroves bordering sections of this creek are festooned with oysters sponges, crabs and other invertebrates. The clarity of the water here is reminiscent of bygone times. Mullet, needle fish, sheephead, redfish, snapper and other fishes are readily seen by any visitor. The creek extends into the interior of the mangrove forest and opens out into Mullet Lake and Mangrove Lake whose bottoms are carpeted in June with filamentous green algae and drifting red algae. The tangled masses of green algae contain several species of mollusks of which the striate bubble (Bulla striata) is most abundant. At the southwest side of Mullet Lake widgeon grass is present indicating that this region probably receives considerable quantities of fresh water on occasion via four mosquito control ditches. Given the variety of marine life in this system and its accessibility by canoe, it represents a valuable educational resource for the Island's schools.

TARPON BAY TO WULFERT CHANNEL

On leaving Tarpon Bay one must circumnavigate a large grass flat delta before heading north to Wulfert Channel at the west end of Wulfert Keys. The grass flats along this side of the Island are extensive and are dominated by turtle grass beyond 1.5 feet M.L.W. In general, the maximum depths at which the grasses occur here are three feet M.L.W. However, in the vicinity of the west power lines off Coral Creek Inlet where the water is unusually clear, the grasses grow at depths of four to six feet M.L.W.

Near the mangrove shoreline the grass beds are intercepted by the Sanibel Shoals, an intertidal sandbar with patches of Cuban shoal weed. Between the Shoals and the shore there are grass beds and accumulations of drifting red algae and the sea lettuce (Ulva lactuca).

These grass flats are extremely "healthy" as evidenced by grass blades 18 to 24 inches long and by the densities of shoots. They contain beds of hard shell clams and formerly populations of the bay scallop. However, one section of this system is unique and that is the large deltoid grass flat at the entrance to Tarpon Bay. Only here did we observe an overt abundance of whelks, hard shell clams, pen shells and the sulfur sponge (Cliona celata). This area is a prime educational as well as fisheries resource.

J.N. "DING" DARLING REFUGE BAYOUS

The bottoms of the several bayous are vegetated with stands of turtle grass and Cuban shoal weed from M.L.W. to two-three feet below M.L.W. Tidal channels meander through the bayous and exit into Pine Island Sound through cuts in the Sanibel Shoals. These bayous support a variety of resident vertebrates and invertebrates as well as being an important breeding area and nursery for fishes, pink shrimp, horseshoe crabs and two species of sea hares. By and large, this region is now a relatively high saline estuary except near the diked Sanctuary Drive in the Refuge. This dike has altered the composition of marine life within the impoundment area and in so doing may have eliminated an important

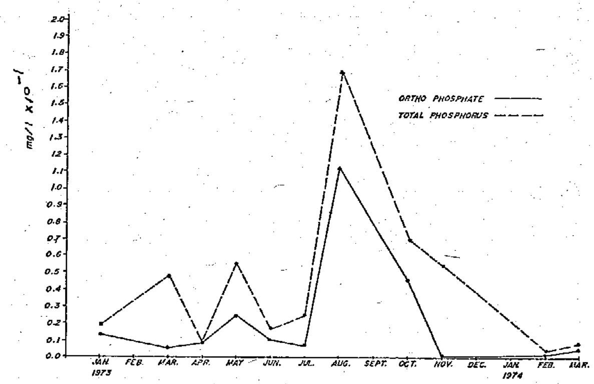


Fig. 15 - Monthly phosphorous values at water quality station 18, Pine Island Sound 1973-1974. (After Duane Hall and Assocs., 1974)

marine faunal breeding and nursery area.

WULFERT BAY

At the west end of the Pine Island Sound side of Sanibel, the Wulfert Keys form a natural group of barrier islands that have created the wind-protected Wulfert Bay which is completely exposed at mean low water. The soft bottom here is sparsely vegetated with turtle grass and drifting red algae. The benthic invertebrate community is probably dominated by species of worms. The waters here are especially turbid because of the fine sediments being easily disturbed by the wind.

THE ALBRIGHT - RUNYON KEY BIGHTS

At Blind Pass between these two keys and Sanibel proper are two shallow backwater areas whose bottoms represent a unique marine habitat. Here and extending into Dinken Bayou the shallow bottoms adjoining the tidal channels are composed of marly-clay-sand and the waters are milky. It is here and maybe only here that large local populations of angel wing clams and burrowing pistol shrimp occur in the island's marine environment. This area is important as a unique natural habitat and as an educational resource.

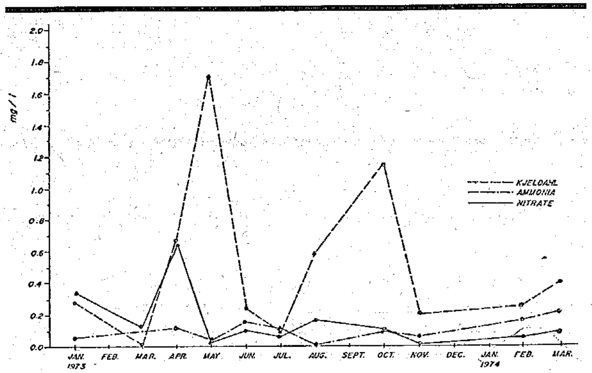


Fig. 16 - Monthly nitrogen values (mg/l) at water quality station 18, Pine Island Sound, 1973-1974. (After Duane Hall and Associates, 1974)

DINKEN BAYOU

In the lower half of Dinken Bayou the waters are milky. Yet turtle grass stands are present and sea squirts and oysters occur along the shores on pilings as well as red mangrove roots and submerged branches. The shallow vegetated bottom of the bayou extends to Mud Pond, whose soft bottom is vegetated with Cuban shoal weed and is exposed at low tides. While this system appears to have adequate tidal flushing, the dead end Castaway canal off of Mud Pond is not well flushed as evidenced by floating debris (including one dead alligator four feet long) and fluid sediments six to twelve inches thick over firm sand. Visible septic tank seepage along the margins of this canal indicate the canal's waters may be polluting Mud Pond and Dinken Bayou.

CLAM BAYOU AND OLD BLIND PASS

The waters in these two shallow, narrow bayous are highly turbid. Yet the soft bottoms are vegetated with Cuban shoal weed to the upper dead ends of both bayous. Permit reports by the Florida Department of Natural Resources (1975) state that only the shallowest of navigable waterways should be permitted. The lower reaches of these passes near the north end of Sanibel's Turner Beach are six feet deep, well scoured, full of schools of fish and are areas of active feeding by the pelicans that roost at the tip of Silver Key and parade on the adjoining sandbar.

Years ago Haas (1940) remarked that the innermost part of Clam Bayou had a white sandy bottom populated by fiddler crabs as well as the marsh clam, Polymesoda floridana, which also was numerous (10-16 per handful) at the inner ends of Old Blind Pass. Even as early as 1940, however, the marsh clam population appeared to have been decimated in Clam Bayou by raccoons. At that time the sandy bottom of Old Blind Pass was the only place on the Island that the pointed venus clam, Anomalicardia cuneimenis, was found. Today the soft sediments of these bayous support a different benthic fauna. As Haas (1940) points out, the Blind Pass area is unique in that it is intermediate between the Gulf and Pine Island Sound tidal areas and receives its fauna from both sides of the Island. This alone is sufficient to consider conserving and managing this area as an educational resource.

We strongly recommend that segments of the Blind Pass area be protected from upland development and over-utilization by people. These segments include Runyon and Albright Keys and their adjoining bights, the Old Blind Pass side of Silver Key, Old Blind Pass and Turner Beach as far east as the dead end of Old Blind Pass.

THE GULF BEACHES AND LITTORAL ZONE

At first glance the marine habitats along the Gulf beaches of Sanibel merit little comment other than that they are attractive. However, their marine life is periodically disturbed by short-term environmental perturbations such as storms and red tides whose waves cast upon the upper beaches windrows of pen shells, Chaetopterus worms and their tubes, surf clams (Spisula solidissima), coquinas, mussels, snails, sand fleas (Emeritia) and crabs. Such an event is a jubilee for shell collectors and a nuisance for others.

In the not too distant future the people of Sanibel and the marine life of the inshore waters and intertidal zones along the Island's Gulf side may have to adapt to the threat of bilge effluents and oil spills offshore if the Charlotte Harbor deep water port is developed.

MAN-MADE CANALS AND WATERWAYS

The environmental aspects of Sanibel's upland canal systems merit additional comments. The canals fall into two categories: the shallow

Table 8 - Popular and scientific names of fishes reported killed by "freezes" at Sanibel, Florida, 1934. (After Storey and Gudger, 1936)

Scientific Name	Local Name	Names Common Elsewhere	Habitats	Local Collections
Seriola sp.	amberjack	amberjack	p	G.B.
Chaetodipterus faber	angelfish, black	spadefish	m & d	
Spheroides spengleri	blowfish, puffer	balloon fish	m & d	
Pomatomus saltatrix	bluefish	bluefish	p	
Lactophyrys tricornis	cowfish	horned trunkfish	ad	
Galeichthys milberti	catfish	sea catfish	ad	G.B.
Felichthys felis	catfish, gaff-topsail	catfish, gaff-topsail	m & d	G.B.
Mystriophis intertinctus	eel, brown spotted	snake eel	s & m	
many sp., several families	flounder	flatfish,flounder		
Mycteroperca bonaci	grouper, black	marbled rockfish	m & d	
Epinephelus morio	grouper, red	red grouper	d	
Haemulon plumieri	grunt, black	common grunt	d	
Hyporhamphus unifasciatus	hound minnow	halfbeak;ballyhoo	sf	
Caranx hippos	jack	crevalle; cavally	sf & ad	
Oligoplites saurus	jack, yellow leatherjack	leatherjack	sf, s & m	G.B.
Garrupa nigrita	jewfish	jewfish, giant	m & d	
Elops sauris	ladyfish	bonyfish; ten pounder	sf	G.B.
Scomberomorus maculatus	mackerel	spanish mackerel	p	G.B.
Mugil cephalus	mullet	striped mullet	s	G.B.
Mugil curema	mullet, silver	white mullet		B.P.,P.S.,T.B.
Strongylura notata	needlefish	gar;needlefish	sf	B.P.,T.B.,G.B.
Menticirrhus sp.	perch, sand	sea mink;whiting		G.B.
Trachinotus falcatus	permit	round pompano		G.B.
Lagodon rhomboides	pinfish	bream;pinfish	ad	T.B.,G.B., P.S.
Trachinotus carolinus	pompano	pampano; pompano	s & m	
Chilomycterus schoepfi	porcupine	balloon fish; spiny boxfish	s & m	T.B.
Sciaenops ocellatus	redfish	channel bass	s & m	
Caranx crysos	runner, blue	hard-tailed jack	sf & ad	
Orthopristis chrysopterus	sailor's choice; pigfish; grunt	pigfish, etc.	d	
Carcharinus sp; Carcharias sp.	shark	shark		
Sphyrna zygaena	shark,hammerhead	hammerhead shark		
Scoliodon terrae-novae	shark,sharp nose	sharp-nosed shark		
Sphyrna tiburo	shark,shovel nose	shovel-nosed; bonnet shark		
Echeneis naucrates	shark sucker	remora;shark-sucker		
Archosargus probatocephalus	sheephead	sheepshead; prisoner fish	s & m	T.B.
Synodus foetens	snakefish	lizard fish	s & m	T.B.,G.B.
Lutianus griseus	snapper,mangrove	gray snapper	ad	
Centropomis undecimalis	snook	rovalia; robalo	s & m	G.B.
Lutianus synagris	spot, red (young Lane snapper)	spot snapper	d	T.B.,G.B.
Tarpon atlanticus	tarpon	tarpon,tarpum	ad	T.B.
Opsanus tau	toadfish	bulldog-fish; scorpion	s	T.B.
Ogocephalus radiatus	toad,rock	batfish		
Cynoscion nebulosus	trout	trout; spotted sque-teague	ad	P.B.,T.B., G.B.
Lactophyrs sp.	trunk	trunkfish		
Echeneis remora	shark sucker		ad	

Habitats Code: surface - sf, medium - m, all depths - ad, deep - d, shallow - s

Local Collections Code: Gulf Beaches - G.B., Pine Island - P.S., Tarpon Bay - T.B., Blind Pass Area - B.P.

(three to five feet deep) Sanibel Estates canal system whose bottom is vegetated with turtle grass and Cuban shoal weed except at its innermost extremities and the deeper (six to twenty feet deep) post 1950 canals that are for the most part seawalled and have steep slopes that grade from the seawalls. Where such canals are not seawalled the banks are eroding except where white and red mangroves have become established.

It is common knowledge that mangroved margins of canals and waterways are desirable as a natural marine resource and as a mechanism for stabilizing and protecting these margins. What is not common knowledge is that mangroves, especially white mangroves, grow rapidly along non-seawalled canal margins leaning out over the water. In times of heavy rains these trees may promote erosion and slumping of the canal banks. Thus, in order to minimize the stress to canal banks, the mangroves and other trees should be pruned. On

TARPON BAY	
Achirus lineatus	Hogchoker
Adinia xenica	Banded killifish
Anchoa mitchilli	Bay anchovy
Bairdiella chrysura	Yellowtail,Silver perch
Chasmodes saburrae	Blenny
Cyprinodon variegatus	Sheepshead minnow
Eucinostomus gula	Silver jenny
Eucinostomus melanopterus	Flagfin mojarra
Floridichthys carpio	Chub
Gobiosoma robustum	Goby
Hippocampus zostecae	Dwarf seahorse
Lepisosteus platyrhicus	Florida gar
Lucania parva	Rainwater fish,Diamond killifish
Menidia beryllina	Silversides
Syngnathus floridae	Florida pipefish
Syngnathus louisianae	Louisiana pipefish
Syngnathus scovelli	Silverstriped pipefish
Ulaema lefroyi	Mottled mojarra

GULF BEACHES	
Bairdiella chrysura	Yellowtail
Chloroscombrus chrysurus	Bumper
Emblemaria atlantica	
Eucinostomus argenteus	Spotfin mojarra
Eucinostomus gula	Silver Jenny
Fundulus similis	Longnose killifish
Harengula humeralis	Red ear sardine
Harengula pensacolae	Scaled or silver sardine
Mugil trichodon	Fantail mullet
Selene vomer	Lookdown
Syngnathus louisianae	Louisiana pipefish
Trachinotus carolinus	Pompano

BLIND PASS	
Eucinostomus sp.	Mojarra
Harengula pensacolae	Scaled or Silver sardine

Killifish - no genus given

PINE ISLAND SOUND	
Eucinostomus melanopterus	Flagfin mojarra

MANGROVES & SANCTUARY	
Archosargus probatocephalus	Sheepshead
Lagodon rhomboides	Pinfish
Menidia beryllina	Silversides
Mollienesia latipinna	Molly
Mugil sp.	Mullet
Orthopristis sp.	Pigfish
Tarpon atlanticus	Tarpon

Killifish-no genus given

Table 9 - List of additional species of marine fishes in the Sanibel Island waters by habitat. (Compiled from Woodburn, 1959; Gunter & Hall, 1965; Hancock, 1969; Fla. Dept. Nat. Res., 1970; Erwin, 1975)

Sanibel the areas that need such a management program include Sanibel Estates, the Dixie Beach Blvd. canal, and the waterways and canals of Dinken Bayou and Clam Bayou.

The soft organic rich sediments of the canals, particularly the pre-1970 dead end canals should be removed in order to improve their water quality and marine life. The tidal flushing and circulation of the Castaway Estates, Del Sega and Sanibel Estates canals could be improved. Indeed in the case of the Sanibel Estates canals an "Act of God" storm may breach the low-lying land adjacent to the Gulf and reopen the original mouth of the Sanibel River, thereby relieving the canals in this area of their sediments accumulated over a period of 25 years. The aftermath of a similar breach on Siesta Key following hurricane Agnes, June 1972, indicates that the rejuvenation of marine life in this canal system would be spectacular.

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APPENDIX 6

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NATURAL ENERGY SYSTEMS

by Mark Brown

As man's influence in any landscape becomes the major feature, planning for future alternatives of land, energy and water use becomes increasingly important. The concern becomes one of insuring long-range values and high quality of life by insuring that lands are put to their highest and best use, that different land uses do not conflict, that energy for productivity is available in the quantities needed, and that there is sufficient high-quality water for the needs of the population as well as natural systems of the area.

This report is concerned with these things, and others; and their influence on long-range values and quality of life. Trends of land use are presented, the energy requirements of productivity are analyzed, and trends in energy availability discussed. The economy of Sanibel Island is analyzed, and the exchanges of major exported and imported goods and services are discussed in light of future ability to maintain balance of payments. A method of calculating carrying capacity as a basis for a vital economy is suggested and demonstrated, and, finally, suggestions for overall well-being and a process for development that will insure long-range values and enhance quality of life are presented.

Sanibel Island, an island of recent rapid growth and urbanization pressure, is shown in Figure 1. The pattern of ecosystem communities that developed throughout the island have changed from the primitive condition with increased activities of man. The patterns of man and nature that developed as a result of abundant natural energies and interface with the Gulf are shown in Figure 1. The purchased energies attracted as the basis for economic vitality and the free resident energies of the region are summarized in the regional model in Figure 2 and balance of payments diagram in Figures 3 and 4.

Energy flows into the region from the sun, wind, and rain as in the past, and now with the development of areas for commercial and residential use, additional energy flows in with electricity, oil, gas, and goods and materials. Some energy is of low quality (in its ability to do work), such as incident sunlight and wind; and some is of high quality, such as water and the fuels that support man's activity. The effective use of all the available energies in a partnership relationship of man and nature is believed to lead to maximum economic vitality.

Current theory and understanding of systems suggests that the greater the energy flows generated from natural systems, the more matching economic activity based on outside fuel energies can be "attracted" and sustained. This is certainly the case of Sanibel Island, blessed, or cursed as it may be, with abundant energies of winds, waves, tides, longshore currents, sunlight, and rainfall. Effective "energy trades" of exports (in Sanibel's case, services) for imports depend on the amount of nature's free energies that can be used to subsidize production processes. If, for example, the purchased energy content of services produced is higher than other competing regions, economic competitiveness and ability to attract and purchase additional energy may suffer. Thus, the purchased energy content of goods and services exported may act as a limiting factor on economic activity sustained by the region.

The combination of inside and outside energies that best maximizes the total flow of high quality energy maximizes the economy of man and sets guidelines for interfacing subsystems of the total environment. Thus, the best strategy for developing long term value and vital economic functioning recognizes the contribution of free energy flows generated from natural systems and maximizes total flows and higher quality purchased fuel energies.

The value of energy flows in ecological systems can be converted into equivalents of energy whose ability to support work is familiar. The basis used is the fossil fuel equivalent (FFE). In this manner the free natural work of ecological systems can be expressed and compared directly to the work of the economic sector; and the relative value of both sectors can be evaluated.

An energy diagram of the many aspects of the systems of man and nature together shows their interplay in ways not usually understood when examined separately. Flows of money, materials, goods, and fuels can be converted to an equivalent basis so that their true relationships can be shown. The model can then be examined in relation to questions of resource protection and management, with suggestions made toward maximizing values and making good interfaces between man-dominated and natural subsystems.

LAND USE AND ENERGETIC MAPS

Land use maps were prepared, using simplified ecosystem communities for natural systems and an energetic classification scheme developed over the past four years for the urban systems (Brown, 1971; Brown, 1973; Odum and Brown, 1975; Brown, 1975).

The 1975 map was drawn from photo interpretation of 1971 A.S.C.S. photography on a base map redrawn from U.S.G.S. quad maps of Sanibel Island, scale 1:24,000. Newer photography (1975) at a scale of 1:9,600 was obtained and used to update original maps.

The classification scheme used for natural systems is a simplified community scheme for overview of the present and past conditions. No attempt was made to delineate the difference between ridge and swale vegetation in the present condition for two reasons. First, the island is in such a stage of transition that no clear lines of demarcation are evident on aerial photographs. Because of altered hydroperiods, successional transition of once cleared lands, and invasion of exotic species, the once evident marsh and ridge vegetation can no longer be delineated with any degree of accuracy. And, second, the minimum cell size, or minimum perceivable subsystem area delineated was 1.5 acres; so while there were areas of "pure" swales of spartina marsh discernable on the larger scale photographs, they were of such a size as to preclude classification.

Measurement of the areas of subsystems was done by cutting up a 7 mil mylar print of the maps and weighing on an analytical balance accurate to .001 grams and multiplying by a conversion factor to transform weight into acreages. Many other methods, including the use of a leaf area index machine and planimetering, have been tried, with this method producing the best accuracy. Accuracy of this method has been determined within 1 percent in past applications. The areas measured are the basis for energy value tables and alternative management calculations.

MODEL OF MAIN COMPONENTS OF SANIBEL

To organize our understanding and show relationships of the main contributions to the value of the area, a simplified diagram was prepared that included the main work processes which contribute value each year (Figure 2). Main flows of energy, both bought and resident, the flows of water and accompanying flows of nutrients are included. By putting the work of man and nature on the same diagram, one summarizes the main processes that contribute to the vitality of the island whether paid for with money or not. The symbols used and a brief explanation of each are given in Appendix A.

BALANCE OF PAYMENTS DIAGRAM

A simple diagram that summarizes the exchanges of energy and money was evaluated for 1975 (Figure 4). Evaluation of balance of energy and money in this manner helps to perceive major contributions to the region's economy and sensitivities to external change. Parameters and coefficients for flows of energy were derived from previous studies of south Florida and Lee County (Brown, 1973; Odum, Brown, et al., 1975). All energy was converted to the same equivalent basis to support work--the fossil fuel equivalent (FFE). A table of conversion factors is included as Table 3.

CALCULATION OF CARRYING CAPACITY

The total activity of man and nature that can be sustained depends on the amount of outside controlling high quality energy that can be attracted

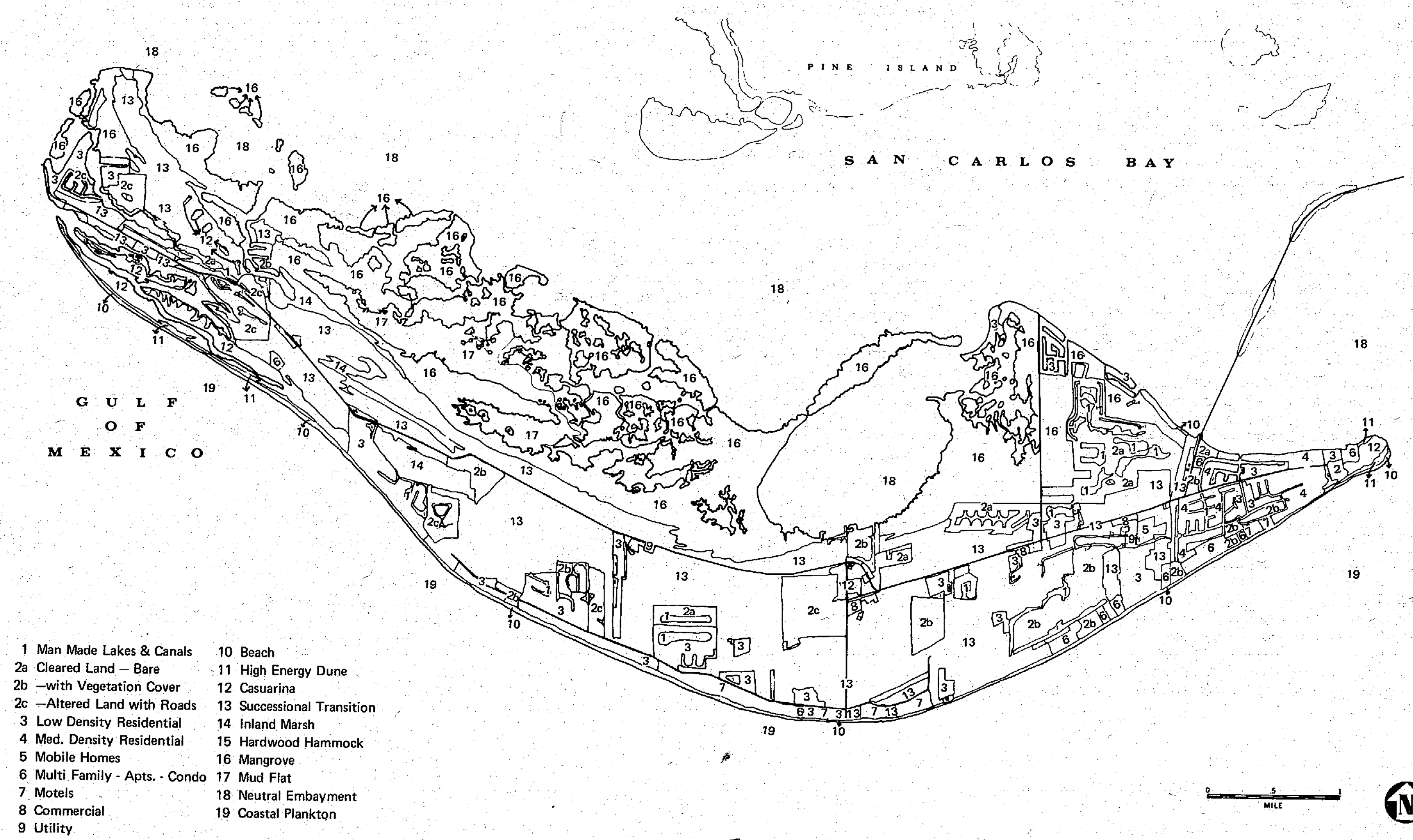

Fig. 1 - Present condition (1975) vegetation and land use for energetic subsystem classification of Sanibel Island. (Compiled by M.T. Brown, J. Bartholomew and R. Costanza).

to add to and amplify energies. Systems compete in attracting outside investments. Those with lower investment ratios (the rate of fossil fuel energies to resident energies) match outside energies with more value from inside and compete better in what they offer for exchange.

Systems compete well so long as their investment ratio is less than that which is characteristic of the larger system within which they operate. In 1974 the investment ratio for southwest Florida coastal communities was 1.9/1. That is to say, for every 1 kcal of natural resident energy, 1.9 kcal of fossil fuel energy was added to it to amplify the resident energy. Investment ratio for Sanibel was calculated and compared to other competing regions.

LAND USE AND LAND USE MAPS

Given in Figure 1 is a land use map for the island, showing the main features of the landscape and man's land use patterns that had developed by 1975.

In the primitive condition, Sanibel Island is described as consisting of a leeward shoreline of mangroves and ridge areas of grassland prairies, and palmetto jungle and mixed woods (Cooley, 1955) with a lower basin through the center of the island of ridges and swales of marshes and seasonal marshes or wet prairies. Wet season rains were collected in the marshes and slowly passed to the central basin of the Sanibel River and eventually, if the rains were of sufficient duration and magnitude to cause a breakout along the coast, passed to the Gulf. Because the energy qualities of water are high, greater potential for maximum work is derived from using waters over a wider area where they generate greater value. Consequently, a pattern of broad marshes and a slow meandering stream had developed to take advantage of this important energy source. Man's manipulation of the landscape has changed this pattern by straightening meanders, deepening the streams, altering stream course, and increasing runoff. Energies that were once used to their fullest now go relatively unused in their original locations and thus the amplifying values of water in these locations are lost.

The early development of lands for agricultural purposes constitutes the major cause of changes in land use until the recent past. Since that time, however, development of the island for commercial and residential use has had significant effect, primarily because of the actual acreages developed and secondarily because of the changes induced to the remaining land areas by drainage and mosquito ditches and the introduction of exotic species.

MODEL OF MAIN COMPONENTS OF SANIBEL

Figure 2 is a regional model of Sanibel Island. The main components of the island system that add value each year are included, as well as exchange pathways of materials, energies, and money. Starting at the right and top of the diagram are the external flows or sources for materials, energies, and money. The first and second components are the beach and dune areas of the Gulf coast where wave energies and coastal winds are high. On the front shoreline (swash zone) that receives breaking waves, the surging waters are received, filtered and returned to the

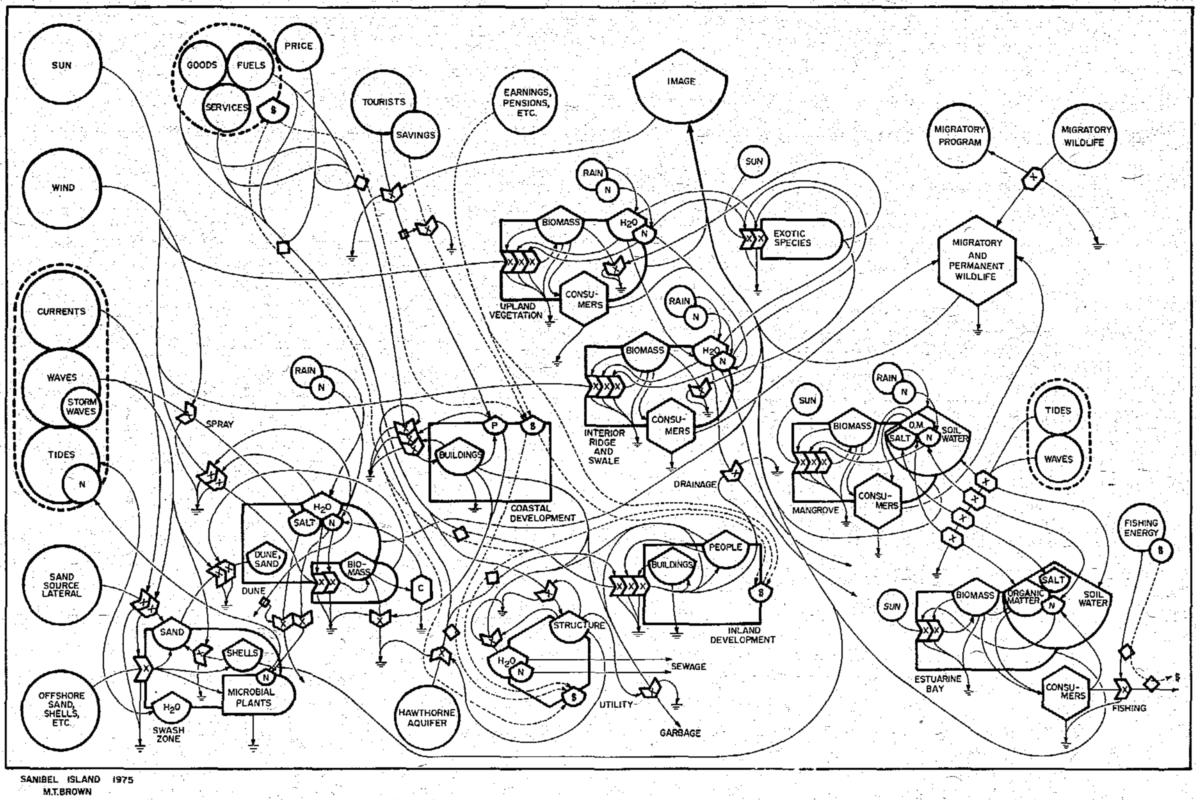

Fig. 2 - Regional model of Sanibel Island showing main components that generate value and major flows of materials and energies that generate vitality.

sea. A portion of the water's organic load is deposited on the beach where it is trapped by the sand filter. The organic material so trapped provides the food base for many invertebrates. That portion not directly and immediately consumed undergoes microbial decomposition and enters local detrital food chains. Breaking waves shift sands and carry sand and shells from deeper waters.

The same energy sources that augment beach accretion are also the prime agents of beach depletion. In the regional sand budget, however, depletion in one area means accretion and deposition in other areas.

Adjacent to, and landward from the swash zone are various types of dune ecosystems. Dunes are the most fragile of the terrestrial ecosystems. The most important stresses affecting dune ecosystems are the paucity of freshwater, salt water spray, wind, and their use by man. The dune is characterized by sparse vegetation that serves the role of trapping and holding shifting sands. Wind, as an energy source, regulates the amount of sand deposition.

The component of urban development labeled coastal development is a primary aspect of the beach and dune system of Sanibel. The quality of the beach, as well as development is important in attracting man. The shells of off-shore molluscs are brought to the beach by wave action. The interaction of users and buildings may have positive effects through increased nutrient flows, but in most cases there is stress to this already fragile system through overuse and development approaches that alter the character of dune vegetation and cause erosion of dune sands.

Inland from the beach and dune systems are the interior "wetlands" or ridge and swale systems and the upland vegetation systems. These systems are undergoing extreme change as a result of actions by man. The direct actions of man in clearing lands, drainage for fast removal of wet season rains, mosquito control ditches, and the introduction of exotic species, have all had their toll in changing the character, structure, and function of these interior ecosystems. Exotic species invasion is characteristic of disturbed areas (Myers, 1975; Duever, 1974). Cleared areas, in the first stages of regrowth, and areas with altered hydroperiods, are prime targets for invasion.

Development on the interior lands imposes direct stress on the natural systems by the actual clearing of lands. The indirect effects of increased runoff which transports high nutrient loads, increased sewage, increased pumpage of ground waters for irrigation of lawns, and increased use of the lands by increasing numbers of people all contribute to heavy stress, and continued change of these lands.

Sanibel Island has no potable water supply. Thus, water is pumped from the Hawthorn aquifer and desalinated by electrodialysis. Desalination is an energy expensive process (detailed calculations are included as Appendix B). As future energy supplies become less available and costs rise proportionally, coupled with increased maintenance costs and decreased efficiency of an older plant, the costs of water for the island can do nothing but rise.

The purchased energy to construct, operate, and maintain the developed portions of the island flows through the system with dollar payments flowing in the opposite direction. Because the two flow in opposite directions, the consumer receives energy and pays out money. The main contributions of income to the island are heavily dependent on a healthy natural environment. Tourist income as shown in the model is a result of tourists being "attracted" to Sanibel Island by its "image." The image is a nonweighable storage of information, but is the product of the total productivity of all components of the island system. Thus, development of coastal and interior areas will at first increase the image to outside visitors, but if development causes degradation of natural areas, a gradual decline of visitors and the income they bring to the island can be the only result. As the ratio of natural (resident) energy flow to total flow of useful work diminishes, the price of services and goods offered for sale must increase, ultimately causing a significant decline in the <u>net</u> income to the island.

Leaving the interior and moving toward the leeward side of the island, mangrove communities are the predominant systems of the estuarine bay coast. The inputs of energy and materials (sunlight, water, nutrients) are shown. It is important to note the overland flow of water and nutrients from the higher lands of the interior. It has been calculated that this source of nutrients provides as much as 10 percent of the total nutrients available to some mangrove systems (Burns, 1975), but further that chloride content of soil water plays a major role in suppression of transpiration. The freshwater input from upland sources is a vital component in maintaining a proper balance of chloride concentrations and that diversion of freshwater from the uplands to offshore regions may suppress natural productivity of mangrove forests (Burns, 1975).

The tides are a major energy source responsible for the transport of nutrients and detrital matter into and out of the tidally-influenced mangroves. With each rise and fall, they deliver an important food source to the estuarine bay food chain...a food chain that eventually ends with commercial and sport fish caught by man, and another important income source to the region.

ENERGY BUDGET AND BALANCE OF PAYMENTS

Figure 3 is a simplified model of energy flow and balance of payments. The region receives, as a basis for its vitality, natural energies inflowing that develop basic resources of lands, beaches, ecosystems, and water. These resources are used to attract incomes of money which include tourist and retirement dollars, and capital investment. These incomes are then paid to buy additional energy inflows in the form of fuels, goods, and services. The attraction of money from sales and tourist dollars is in competition with other regions and, thus, the amount of money obtained and energy eventually bought depend on the region's ability to maintain a balance of payments. This depends ultimately on world-wide prices of fuels and the availability of monies from external sources. If prices increase, and incomes decrease (ultimately because of national energy shortages), the purchased energy available to the island will be less. In this way, the diagram indicates the extent to which the island's total vitality is based on external energy availability and effective maximization of free resident energies.

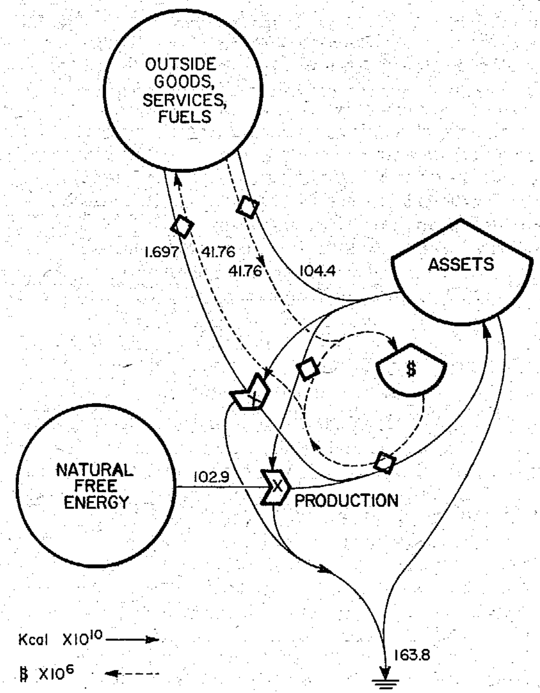

Fig. 3 - Aggregate energy flow diagram showing the interaction of bought energy with free resident energy and balance of payments.

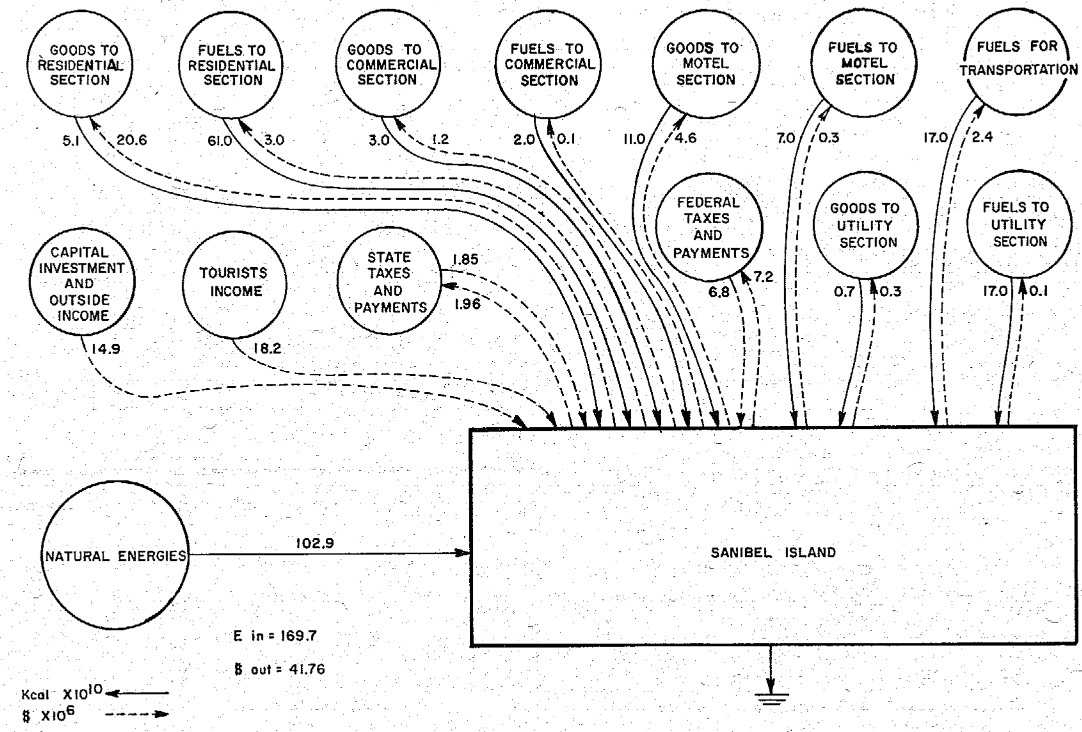

Fig. 4 - Balance of payments diagram showing the main energy and money flows by source and exchanges that generate a vital economy.

Figure 4 is a breakdown of the flows in Figure 3. Tabulated in Table 4 are the major components of Sanibel's energy budget and the percentage of the total. Natural energies contribute approximately 38 percent of the total energy that Sanibel Island consumes in indirect ways, but are of great importance to the total vitality of the system.

Tourist income contributes approximately 45 percent to the island economy, the remainder coming from capital investment and outside income. With an economy so heavily geared to tourist dollars, effective maintenance of natural energies, and those natural systems they amplify, is of prime importance.

CARRYING CAPACITY OF MAN AND NATURE

Determining the carrying capacity for man is much more complex than it is for other species, and as such, has to be treated as a complex problem. Carrying capacity is usually thought of as the number of individuals of a given species that an area of a given size will support. When applied to industrialized man, a better definition relates carrying capacity to energetics. Just as one can increase the carrying capacity of a range for cattle by the addition of energy (fertilizer, irrigation, etc.) the carrying capacity for man has increased with every increase in fossil fuel utilization.

Carrying capacity for man, then, is in direct proportion to the energy he has at his disposal. Sanibel Island could conceivably hold 100,000 people if there were energy enough to maintain order... energy enough to obtain potable water, treat sewage, incinerate garbage and build the roads, hospitals, and government services necessary, as well as defer the host of other "environmental" problems that are a consequence of high densities.

The problem of determining carrying capacity of environments becomes a problem of obtaining a sufficient supply of energy to support the population. In 1973 Hubbert estimated that the United States had tapped the last of its easily accessible cheap energy supplies, and for the next century will see a decrease in the total reserves (Figure 5). Odum (1975) calculates that the "net" energy available to society, after the energy costs of obtaining future supplies is subtracted, has peaked and is decreasing. In all, the energy picture for the future is not bright. Decreasing availabilities mean higher competition and higher prices for the stocks that remain. Those regions within the total economy that can maintain balance of payments with effective "energy trades" will by that aspect alone guarantee future energy supplies.

Regions use purchased energy to add to and amplify free resident energies, combining them in many ways for export and sale to outside markets. Sanibel Island uses purchased energy to provide, operate and maintain structure that in essence amplifies the free resident energy of beaches, bays, mangroves, and wildlife. The island "exports" a service to outside markets in the form of an excellent environment for vacationers to spend leisure time. The purchase energy content of this export determines the price; the more free resident energy that is utilized in providing the service, the lower the asking price.

Competitive position is enhanced with the effective maximization of free resident energies, by amplifying them with small flows of bought energies. Effective energy trades are those trades of exported goods and services for imported energies where the result is a net gain. In Figure 3, it is shown that Sanibel Island exports services with an energy content of 104.4×10^{10} kcal, and imports energy totaling 169.7×10^{10} kcal, or an energy trade of 1.6 to 1. In other words, for every 1 kcal of energy exported, Sanibel obtains in return 1.6 kcal of energy States exports 1 kcal of energy to the OPEC nations and get in return 8 kcal; before the 1973 price increases our energy trade was 24 to 1).

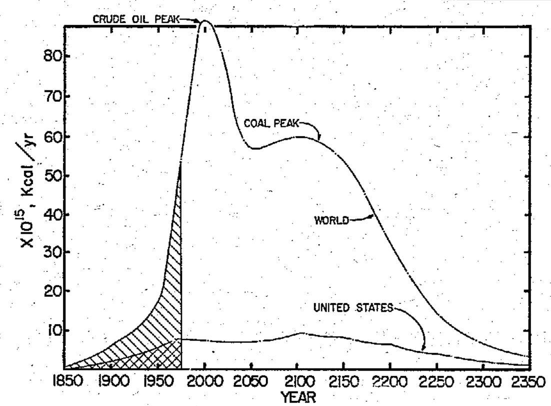

Fig. 5 - Graph of world and United States remaining energy reserves (crosshatched area is energy used to date). Estimate of combined production cycle of crude oil and coal for the world and United States. (Estimates as of 1971 and 1972). Data from Hubbert, 1973. (Based on 2×10^{12} metric tons gross energy).

During times of cheap energy prices and abundant supplies, effective energy trades have little consequence, but as prices rise with scarcity, competition and purchasing power play a larger role. The higher the energy trade, the greater dollar return, and, thus, the greater the purchasing power.

The ratio of purchased energy to resident natural energy is a method of evaluating the relative economic positions of regions. This ratio expresses the level whereby a region adds to and amplifies natural energies to do the work of producing goods and services. The "investment ratio" of areas similar to, and in competition with, Sanibel Island is 1.9 to 1. To remain in competition with these areas, Sanibel Island should strive for an equal or lower ratio. For, if the island's ratio is higher, sold services will contain a higher portion of purchased energy than competing regions, and prices by necessity will be higher.

The investment ratio for Sanibel is calculated in the following manner:

$$\frac{\text{total purchased energy}}{\text{resident energy}} = \text{investment ratio}$$

$$\frac{169.7 \times 10^{10} \text{ kcal}}{102.9 \times 10^{10} \text{ kcal}} = 1.65/1$$

The investment ratio for Sanibel is lower than competing regions. However, with growing populations and the increasing energy flows they require for control of the environment, the ratio is changing. To equal other competing regions' ratios, Sanibel need only grow 15 percent at current energy consumption rates. Looking at it another way, Sanibel's energy consumption can increase by 15 percent and still remain competitive.

ALTERNATIVE FUTURES FOR SANIBEL

Calculations for energetic carrying capacity estimate the total purchased energy Sanibel Island can "attract" and still maintain a vital economy and competitive position. This value (25.81 kcal/yr), when converted to population figures using per capita energy figures for the present condition, shows that Sanibel could conceivably allow a total average yearly occupancy of 13,300 people to reside on the island. Using current ratios of permanent vs. tourist population, this would mean approximately 9,200 permanent residents and average yearly occupancy of seasonal visitors totaling 4,115 (or 125,000 tourists staying for 12 days).

However, a cautionary note should be included. There is increasing evidence that costs for services and increasing population densities do not exhibit a linear relationship. The energy costs associated with increasing population densities may increase by some greater function, so that a 15 percent increase in population may require a 25 percent increase in energy consumption to provide necessary services. It is also important to note that if per capita consumption of fuels, goods, and services continues to increase, population increases should be even less. The carrying capacity for best economic development indicates the level of purchased energies that may be attracted, for the island to maintain competitive position. All increases in population must be calculated against increases in per capita energy consumption

It has been estimated that there are about 4,000 additional dwelling units recorded and approved for Sanibel Island (WMRT, 1975). Calculations from the land use map, assuming three dwelling units per gross acre of cleared lands, confirm this. Four thousand additional dwelling units would double Sanibel's present population, at the same time more than doubling Sanibel's present purchased energy requirements. The investment ratio or ratio of purchased energy to resident energy would be 3.3 to 1, a ratio far exceeding that of other competing regions, and equaling almost that of the urbanized areas of Ft. Myers and Naples! In other words, with current development trends, Sanibel can expect population densities, and the associated decreases in a quality environment, that have been experienced by these mainland communities.

On another note, WMRT (1975) estimates that the number of possible dwelling units based on projections using all zoned lands could reach as high as an additional 16,000 - 24,000 units. A medium value, then, could be 20,000 additional dwelling units; add to this the existing 4,000 units and Sanibel Island could have as many as 24,000 occupied dwelling units.

WMRT assumed occupancy rates of 2.25 to 3.9 when computing populations. Lee County Planning Dept. data (1973) shows approximately 1.5 people/dwelling unit; so, for the purpose of this calculation, 2.0 people/dwelling unit was used as an average. With this value, then, in the foreseeable future there could be as many as 48,000 people living on Sanibel Island. Add to this figure an increased number of tourists (assuming the same ratio as existed in 1974), approximately 21,000, and the total average yearly occupancy of Sanibel Island will reach approximately 69,000 people!

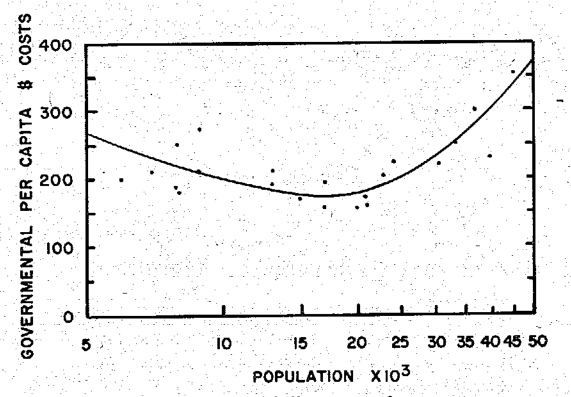

Fig. 6 - Graph of per capita dollar costs of government vs. population size. Source: 1972 Florida Census of Local Government Finances. Commission on Local Government, 1973.

The graph in Figure 6 shows the nature of increased per capita governmental costs vs. population size for various cities throughout Florida. It is interesting to note that the optimum city size according to this data is roughly about 15,000 people. But more important, the graph indicates that should Sanibel increase its population size to 48,000 people, per capita government cost will rise about 40 percent.

Conclusions and Recommendations

Sanibel Island should recognize and work towards a leveled or steady state economy. If there are general shortages of power developing in the United States, either because fuels are unavailable or because fuels are more expensive to get, the economy may enter an inflationary state. With fuels costing more, the amount of work done for each unit of money spent is less, requiring an increase in costs for goods and services. Then the monies available to tourism, retirement incomes, and investment will diminish. If there are national leveling tendencies, they will have a sharply amplified effect on Florida. If development occurs during economically favorable times, when the costs of goods and services are relatively low, decreased economic position, when goods and services are more expensive, may make environmental costs (water, electricity, and sewage systems) too high, thus lowering the carrying capacity of the island.

By recognizing that leveling is required eventually, the island may make moves toward insuring economic stability and maintaining a competitive condition by keeping further growth related to environmental resources and ability to pay. Borrowing too heavily against future energy supplies to finance present growth may lead to instability.

As land becomes more scarce and costs per acre continue to rise, there is the tendency toward high-rise development. The resulting high concentrations of people, cars, energy use, and environmental loads may make for a less secure economic status, if there is a national recession in fuel and resulting economic inflation.

To achieve a leveled or steady state economy there are several alternative guidelines that could be implemented through existing democratic processes.

(1) Provide limits to high power density usages such as high rises, high

density condominium developments and the concentrations of heavy industry. When energy concepts are applied to urban systems, we find that high energy concentrations result in more energy loss per unit of work than do lower concentrations.

(2) Maximize diversity of the region on the principle that added value emerges from the interactions of a variety of land use types in the same area. Large scale developments done on the mass production basis should be discouraged since they work against this principle. Since value or quality of life emerges from having a variety of human and natural activity available, this principle applies within any scale system from the variety of activities of a park to the variety of land use systems of a region.

(3) Develop incentive to maintain and improve existing areas of development through higher taxes on new development, lower taxes on non-developed lands and extend municipal services to existing systems before newly developed areas.

(4) Establish special incentives for the development of low energy communities and habitats that maximize the available natural energies as well as fossil fuel energies through a sympathetic relationship with the surrounding environment.

(5) Reevaluate existing zoning policies, established under rapid growth conditions for controlling successional, low diversity interface problems of concentrated energy utilization. Present zoning techniques may work against the stability of the city by insuring a low diversity, high energy system.

(6) National leveling trends and the amplified effect on Florida may decrease demands for new housing, in which case lands cleared of natural vegetation in preparation of development that never occurs lowers diversity, increases runoff, reduces total energy flow through natural systems and in general stresses natural systems needlessly.

Assessing the impacts of increasing populations on the man-dominated systems and economy of a region is a difficult task and can only be performed accurately after the fact, but trends indicate that future carrying capacities will be less than present values. In that light, any decision to increase the population density of Sanibel Island should be made only after presently committed lands have been fully developed and their true impact assessed.

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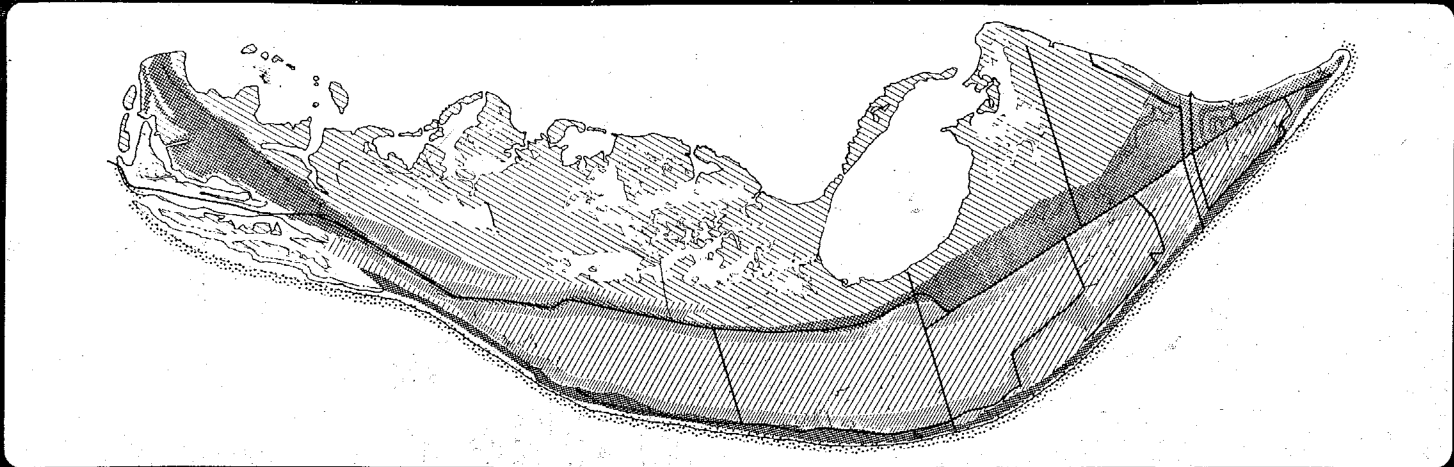

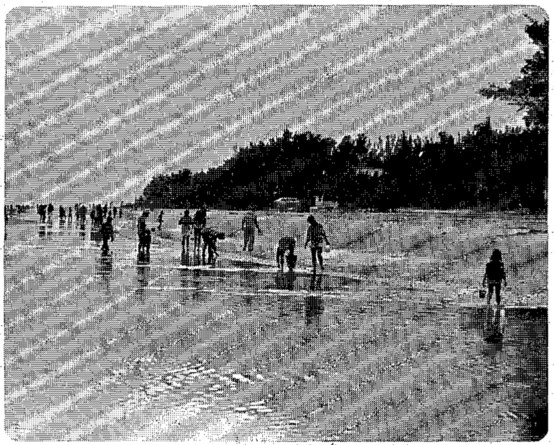

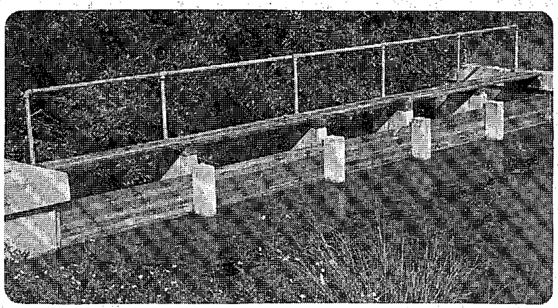

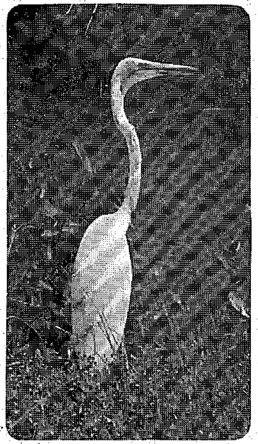

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